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OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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1. Description *and* Correlation *of the* Bournemouth Beds. Part II. Lower *or* Freshwater Series. By J. Starkie Gardner, Esq., F.G.S. (Read June 8, 1881.)

About two years ago I had the honour of laying before this Society a description of the marine beds of the Middle Bagshot, exposed between Highcliff and Bournemouth*. In continuation of my former paper, I now propose completing the description of the Eocene cliffs of this part of Hampshire, as far as Poole Harbour.

These are of freshwater origin, and chiefly interesting on account of the fossil flora recently obtained from them. This appears to be the most extensive and varied yet brought to light from the Tertiary formations; and its study, even now, promises to modify the views held as to the age of very many of the similar fossil floras described from other parts of the world. The Palæontographical Society has undertaken to publish the entire British Eocene flora; and the first parts, comprising the ferns, have already appeared. To illustrate the relative importance of the flora of Bournemouth, I may mention that there are 19 species of ferns described from it, and that only 10 have been met with in all the other British Eocenes and Oligocenes, including Bovey Tracey, and three of these are also found at Bournemouth. Notwithstanding this, few plant-remains are obtained by collectors; for their distribution at Bournemouth is extremely local, and no detailed description of the cliffs containing them has yet been published. A principal object in bringing the present paper before the Society is therefore to indicate the exact position of the fossil-bear-

* Quart. Journ. Geol. Soc. vol. xxxv. p. 209.

ing beds. The literature of the subject is not extensive, no writer previous to 1827 having even referred to the cliffs of Poole Bay, although the Bagshot beds of Alum Bay, Studland, and Corfe had frequently, since 1800, been described or alluded to.

In 1827, Sir Charles Lyell noticed them, as stated in my former paper*. The Rev. P. B. Brodie seems to have been the first, in 1842, to call attention to the occurrence of distinct fossil plants in clay to the east of Bournemouth†, referring them to Lauraceæ, Amentaceæ, and Characeæ. Mantell‡, in 1844, adopted Brodie's views, and again, in 1847§, mentioned the occurrence at Bournemouth of "the same species of plants as those found at Alum Bay." In 1847 also Prof. Prestwich‖ connected the Bournemouth and Alum-Bay sands and clays with the Bagshot of the London basin; and in 1849¶ he determined the position of the Bournemouth leaf-bed to be from 300 to 400 feet higher in the series than that of Alum Bay. The fossil leaves are referred to, but this time from the west of Bournemouth; and, owing to a local patch only having been examined, the species were thought to be few. In 1851, Mantell** introduced some notes on the "foliage of Dicotyledonous trees," from "thin layers of sandy clay in the cliffs west of Bournemouth;" and in another work†† there is a footnote upon the temperate character of the flora compared with that from Sheppey. In 1855 Trimmer‡‡ used the term "Bournemouth sands and clays" in correlating them with beds of the New Forest. In 1856 De la Harpe§§ recognized 22 species of plants from Bournemouth, 13 of which he supposed to be common to Alum Bay; and in 1859‖‖ we find that Heer was acquainted with the fact of the occurrence of leaves there and elsewhere in the Hampshire basin.

In 1862, in the 'Memoir on the Isle of Wight' by the Geological Survey, it is said that the fossil floras of Bournemouth, Corfe, and Alum Bay are "identical," although we now know that few of the characteristic forms are common to these localities. They are said to be "on exactly the same horizon" without reference to Prof. Prestwich's statement that from 300 to 400 feet of strata intervene. During 1865–69, Mr. W. S. Mitchell was engaged, with the assistance of a committee appointed by the British Association, in collecting specimens and information respecting the fossil leaves; and brief notices were read by him at the meeting of the British Association in 1866. His attention was principally directed to the Alum-Bay beds. The first illustration of a fossil leaf from Bournemouth ever published was of a *Gleichenia* by Mr. A. Wanklyn¶¶ in 1869, or

* Quart. Journ. Geol. Soc. vol. xxxv. p. 209.

† Proc. Geol. Soc. vol. iii. p. 592.

‡ Medals of Creation, vol. i. p. 193.

§ Geol. Isle of Wight, p. 169.

‖ Quart. Journ. Geol. Soc. vol. iii.

¶ Quart. Journ. Geol. Soc. vol. v. p. 43.

** Geological Excursion round the Isle of Wight, 2nd edition. Supplement.

†† Fossils of the British Museum, 1851, p. 51.

‡‡ Journ. Roy. Agric. Soc. vol. xvi. p. 125.

§§ Bull. de la Société Vaudoise des Sciences Naturelles, 1856.

‖‖ Flora Tertiaria Helvetiæ, vol. iii. p. 314.

¶¶ Ann. and Mag. Nat. Hist. ser. 4, vol. iii. p. 10, pl. i.

fifteen years after Edward Forbes *, in his Anniversary Address to this Society, had called attention to the necessity of doing something with these floras, and suggested that the Palæontographical Society should direct their attention to them. In 1870 Mr. Mansel-Pleydell, in the 'Flora of Dorset,' alludes to the plant-remains from Bournemouth.

From that time nothing has been written upon the subject, except my own observations, referred to in the first twenty pages of the Palæontographical Society's Memoir on the Eocene flora.

The cliffs which comprise the Bournemouth freshwater series extend from Poole harbour to beyond Bournemouth, and present escarpments averaging nearly 100 feet in height, cut up by many chines. They are composed of yellow, white, and brownish sands and clays possessing hardly any of the bright-red colouring so conspicuous at Alum and Studland Bays; yet in the sunlight and after heavy rains their ever varying shades of buff and yellow, orange and black, with their crown of dark pine woods, present effects not seen on any other British coast. Looked at in the summer, when baked by the sun and incrusted with blown sand, they appear monotonous, and for years were supposed to be unfossiliferous and on the same plane, much of them being jealously guarded private property.

The freshwater Middle Bagshot series is represented at Alum Bay by the unfossiliferous beds 19 to 24 of Prof. Prestwich's section†, 240 feet thick. It has not been separated, if really present, from the Lower Bagshot beds in the London basin. Besides the cliff exposure at Bournemouth, sections are visible inland in many neighbouring pits and railway-cuttings; in all probability also the extensive deposits of Bovey Tracey are of approximately the same age. These beds cannot be correlated, except palæontologically, with the continental Eocenes, the only beds with similar matrix containing leaves being, I believe, found at Aix-la-Chapelle.

I have placed the Bournemouth series in the Middle Bagshots, drawing the line between these and the Lower Bagshots at the pipeclays of Corfe, Studland, and Alum Bay, on account of the great dissimilarity of the floras contained in them. The Bournemouth flora is distinct from the older floras, and passes upward into the Oligocene flora without any perceptible break, but does not pass downward into the Alum-Bay series. The two series are, in addition to this, lithologically distinct—the older being characterized by thicker and purer clay deposits and coarser and often deeply stained sands, the newer by black or sandy clay beds of small extent and fine yellow sands. Pipe-clays are everywhere dug from the one, and brick-earths mainly from the other. No flints or stones are ever found in these deposits; and the coarser material is quartz grit.

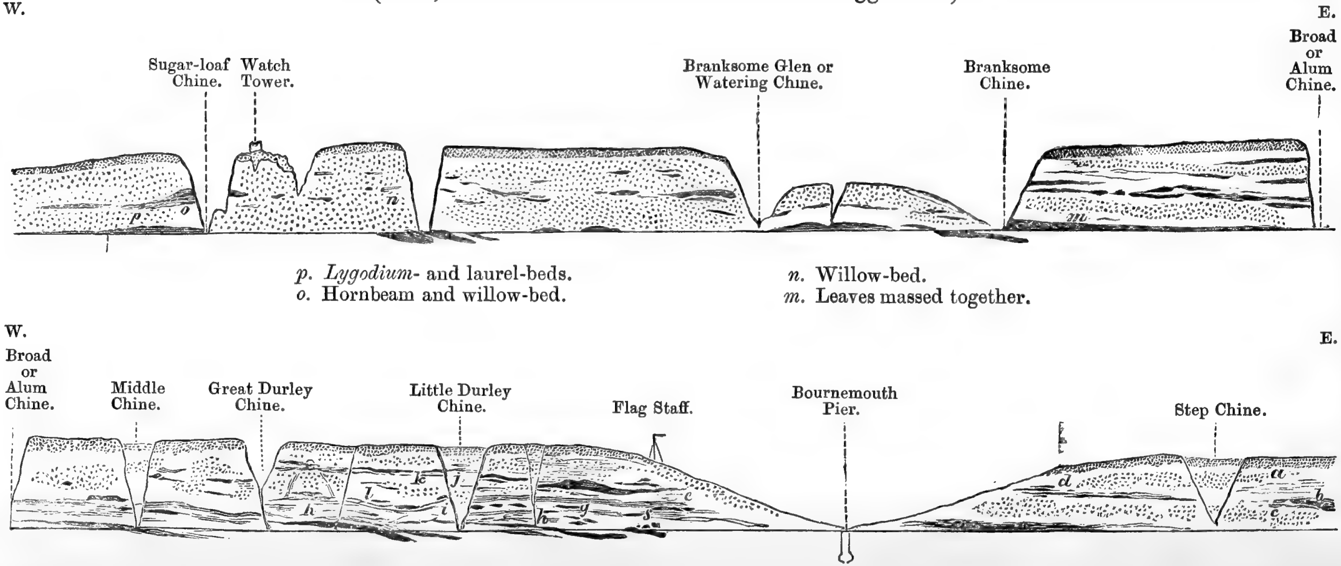
Description of the Beds.

In describing the beds of this part of the Bournemouth section, I find it most convenient to take what are presumably the oldest first.

* Quart. Journ. Geol. Soc. vol. x. p. 56.

† Ibid. vol. xxxv. p. 226, fig. 6.

Fig. 1.—*View of Cliffs between Poole Harbour and Boscombe, showing position of Plant-beds, &c.* (Scale, 5 inches to 1 mile. Vertical scale exaggerated.)



p. *Lygodium*- and laurel-beds.
o. Hornbeam and willow-bed.
n. Willow-bed.
m. Leaves massed together.

l. Rolled masses with leaves.
k. *Myrica*-bed.
j. Palm-bed.
i. Rolled leaves.
h. Lignitic sand with bored wood.
g. *Gleichenia*-beds.
f. Coast-guard beds.
e. Reimbedded ferns.
d. Aroid and *Eucalyptus*-bed.
c. Fern-bed.
b. Marine clay.
a. Marine sands passing into freshwater.

The sequence of beds deposited by river-action is, it is well known, rather horizontal than vertical, the sediments nearest the head of any valley that has been silted up being usually the oldest. To take a familiar instance, the plains of the Rhone above Lake Leman, were doubtless once a portion of the lake progressively filled in; and if sections through them were now visible, these would present many miles of horizontal stratification, only cut through and disturbed near the surface by the subsequent shifts in the course of the river: yet though continuous and horizontal, the sediments in the upper part of the valley are, of course, enormously older than those forming at the present outfall of the river into the lake. There are many indications that the Eocene river which deposited the Bournemouth strata flowed from a westerly point; and therefore the western extremity of the cliff-section is inferred to be the oldest. Moreover close examination reveals that the clays, sands, and grits, which do not appear at first traceable for more than a few yards, are really often in parallel zones of some extent, and repose at an angle which exposes at least 400 feet of their thickness.

It is scarcely necessary to describe the somewhat complicated formation of the cliffs in minute detail. Their general appearance seaward is that of a confused mass of lenticular patches, now of sand, and now of light- or dark-coloured clay, suggesting forcibly a transverse or oblique section across an old river-valley. The sections up the chines do not present the same lens-shaped patches, but more continuous beds; and it may therefore be assumed that they are somewhat more in the direction of the former channels.

The cliffs fronting the sea may be divided into three groups, which are not difficult to distinguish when unobscured by blown sand or débris.

From Poole Harbour to Bateman's Chine there are masses of dark clay enclosed in the sands. The principal mass is 1100 feet long and about 35 feet above high water. It consists of a continuous band, 4 feet thick, of yellowish sandy clay, overlain by darker clay of varying thickness, and attaining 40 feet at its eastern end. It terminates in the chine, and is barely traceable across to the other side. At the base of this dark clay there are in several places lighter clay patches containing leaves, the most important being situated at about 100 yards to the west of the chine just mentioned. The exact section is:—

	ft.	in.
Gravel, a few feet		
Cross-bedded coarse sands with rolled pipe-clay.....	12	0
Marly white clays, unstratified, with a layer of bright yellow sand	4	0
Slate-coloured clay, with frequent layers of pyrites towards the base.	11	0
Black clay with leaves	0	6
Shading to fawn-coloured clay with leaves	0	6
Regularly stratified yellowish and white sand alternating with pinkish sandy clay. (This bed is continuous for 1100 feet.)...	4	0
White and buff sands.	25	0
Black clays, often obliquely, sometimes vertically bedded, usually concealed by débris.		

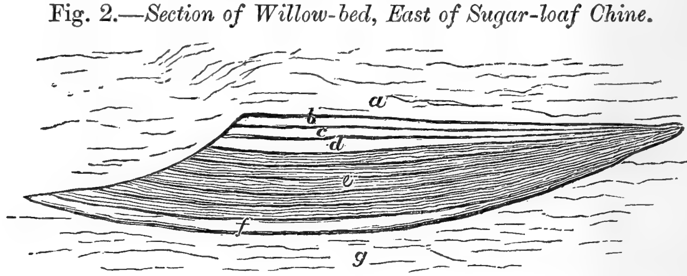
The prevailing leaves are simple and either laurel-like or willow-like, and frequently attached in numbers to the twigs. A large

pinnatifid leaf of the form of *Stenocarpus* is, together with a compound *Acacia*-like leaf, entirely confined to this patch. Other characteristic leaves are a small oval *Smilax* with a thin twining stem, a *Glyptostrobus* (?), and a *Lygodium*. The only fossil feather yet found, so far as I am aware, in England was obtained in this bed. Another patch at the angle of the chine has only single detached leaves, smoothly spread between the surfaces of laminated sandy clay, and is characterized by the great preponderance of a large hornbeam-like leaf and the very large stipules and serrate leaves of, apparently, a willow. Nearer Poole Harbour one or two small patches of clay occur; yet these sometimes contain leaves quite peculiar to them.

Unlike the rest of the cliffs eastward, the longest sections of the clays up to this point face the sea and do not extend far in the upchine sections.

The second group extends from Sugar-loaf Chine to Watering Chine (fig. 1); and the cliffs are somewhat differently composed. The black clays are almost unrepresented; and in their place are observed numerous small and always lenticular patches of light-coloured clay, not arranged in any horizontal series, but sometimes three or four overlying one another at one spot. They are either composed of pinkish laminated sandy clay, hard white sandy marl, or pure white pipe-clay. The first variety has sometimes faintly marked impressions of leaves, while the latter are unstratified and without fossils. Only one considerable patch in this group, occurring about 100 yards to the east of the Branksome watch-tower, has yielded well-preserved fossils. It is 25 feet across, composed of white and drab and pinkish clay, overlying black sandy clay; and it contains remains of insects, flowers, leguminous pods, small detached willow-like leaves with smooth or serrated margins, stipules, laurel and *Diospyros* leaves. When leaves occur in it that are met with elsewhere on this coast, they are small and stunted. This lenticular patch is composed as follows (fig. 2):—

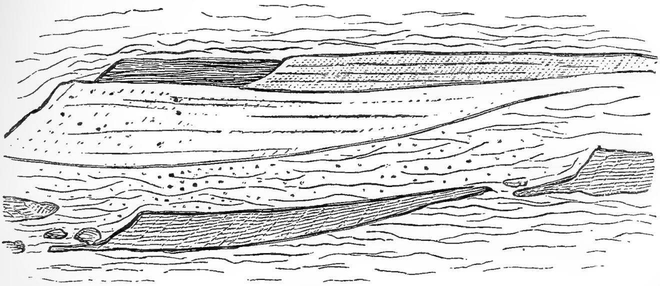
Fig. 2.—*Section of Willow-bed, East of Sugar-loaf Chine.*



		ft.	in.
a.	Buff quartzose sand		
b.	Coarse red irony sand with iron layer at base	0	4
c.	White clay, stained slightly yellow in places, with leaves	0	6
d.	Cinnamon-coloured clay, with leaves	0	8
e.	Blackish clay in layers	7	0
f.	Yellowish sandy clay	1	0
	White sand	0	1½
	Coarse red sand	0	4
g.	Quartzose sand to beach.		

The lenticular patches, both of clay and sand, are frequently cut through their steep face to the west, and redeposited, the clays being rolled into small boulders and pellets (fig. 3).

Fig. 3.—*Example of Clay and Sand Beds, imbedded in loose Sands presenting Escarpments to the West, East of Sugar-loaf Chine.*



Under the leaf-bed just described five reefs of pyrites* are visible at low water, running south-east with a W.S.W. dip. These are succeeded by dark clay dipping E., about 1 in 50, in which I observed a palm trunk *in situ* and numerous spines, and a bed of hard lignite, from 6 inches to a foot thick, underlain by brown clay with roots and covered by pyrites†. Rocks of pyrites again occur opposite Watering Chine, although they are never quite uncovered by the sea; and by means of a diver I was able to trace them two miles seawards towards Alum Bay.

In the third section of the cliffs, from Watering Chine to the Bourne valley (fig. 1), several distinct horizons can again be traced. At the base there are (1) black clays, obliquely bedded, recalling those at the base of the fossiliferous series nearer Poole. Then, in ascending order, interrupted and often separated from each other by sands, (2) black sandy clay, (3) ironstone, (4) small patches of pipe-clay or lightish sandy clay imbedded in sand. Tracing these from bluff to bluff, the dark-sandy-clay (2) and the ironstone (3) horizons are the most distinct, and dip some 3° E.; but the pipe-clays (4) are for some distance only represented by an irregular line of small lumps. Up the chine these horizons seem to rise 4° or 5° N.W. About halfway towards Bournemouth the dip brings in, at first close to the top of the cliff, a new horizon of sandy clay (5), with indistinct leaf-impressions at the angle of Broad Chine. The lower bed of dark sandy clay (2) can be traced across Broad and Middle Chines, until at its western angle it is carried below the beach; and soon after the ironstone horizon (3) also dips out of sight. The horizon can, however,

* Many beds charged with iron or lignite, though friable in the cliffs, become indurated by sea-water.

† Since writing this description, a very extensive bed of lignite was left exposed, just west of Watering Chine, for a few hours by a violent easterly gale and spring tides.

be traced for several hundred yards along the beach, after easterly gales, and is seen to consist of several layers of ironstone, separated by clays and sands charged with lignitic and vegetable matter, and full of *Teredo*-bored wood. In the meantime the line of light-clay patches (4) becomes more defined; and although the clays are often merely rolled boulders, they assume importance from the beauty and rarity of the fossils which even the smaller isolated fragments contain*. These boulders indicate how many leaf-patches were broken up and swept away after they had become indurated. The upper dark-clay zone also becomes of great importance; for it contains well-preserved fossils in at least two places, the one being characterized by the abundance of a *Myrica*-like leaf, the other by a large pinnate palm.

The last bluff on the west side of the Bourne, however, is by far the most important palæontologically. It is traversed by the upper dark-clay zone (5), with fossils which are comparatively not well preserved; but the light-clay patches (4) below are large and actually crowded with leaves. Towards the western end of the bluff the two horizons are widely separated by an immense wedge of indurated and laminated sands; but under the Highcliff mansions they approach to within about a dozen feet of each other, a mass only 10 or 12 feet thick of orange sand and ironstone separating them. The lenticular clay basin below this sand appears to have been known for several years as a spot for collecting; and it is regrettable that some systematic care was not bestowed upon it; for its margin is now almost reached, and scarcely any further specimens can now be obtained. It was characterized by an abundance of *Gleichenia*, which seems to have grown in a marly bed still pierced by rootlets, and also by what appears to be a distinct conifer, a *Godoya*, and *Iriartea*, all these being very rarely, if ever, met with elsewhere. The cliff-section exactly under the flagstaff of the Coast Guard station is as follows:

		ft.	in.
	Light to yellow sand	10	0
	Black sand	1	0
	White sand	5	0
Upper horizon of clays.	Black clay	3	0
	Orange clay	1	0
	Black clay	12	0
	Light clay with leaves	2	0
	Light sand with lignitic grains	2	0
	Hard white sand	2	0
	Drab-and-white mottled clayey sand, passing to white sand	18	0
Lower horizon of clays.	Although no clay is present here, there are patches a few yards east and west abounding in leaves.		

The rest of the cliff is composed of grits and sands containing iron, with white sand containing lignitic matter near the sea-level.

Twelve yards further on, the mottled sandy clay contains débris of palms, ferns, rushes, &c. Below this a few yards to the east occur by far

* From one of these a large part of a pinna, the spathe, and fruit-stalks of a date-palm were obtained.

the richest fossil-bearing beds. The details are:—first a layer of quite decomposed *Teredo*-bored wood; then compact blackish clay in a wedge-shaped mass, 36 yards long, 10 feet thick, with a water-worn and uneven upper surface, laminated, highly pyritous, containing between some of its layers detached pinnules of *Osmunda lignitum*, twigs of *Sequoia Couttsiæ*, spines, a small leguminous pod, and other fruits or seeds*. [The leaves &c. are black and lustrous, but very difficult to preserve. The large frond of *Chrysodium*, figured pl. i. 'British Eocene Flora,' and leaves of palm are from this bed.]

The black clay passes into a cinnamon-coloured clay containing abundant and exquisitely preserved leaves, even the commonest of which are as yet undetermined.

The cinnamon clay rests upon a band of ironstone 1 foot thick, and this upon 5 feet of coarse angular grit; and then follows a patch about 1 foot thick of light drab and very tenacious clay, full of a small, variable and peculiar although as yet undetermined leaf, and of a *Smilax*. Below this, and separated from it by 30 inches of whitish and orange, more or less lignitic sand, are two beds, 4 or 5 inches thick, of sandy clay, finely laminated and full of leaves, becoming, in fact, towards the base a mere mass of decayed vegetable matter. The leaves contained in them are much handsomer, larger, and in far greater variety than those of any other of the beds. From this point to the pier no fossiliferous beds are exposed; but in excavating the foundations of the club-house, which is in their direct line of dip, it is stated that leaves were met with.

At 390 paces east of the pier, where the cliffs again rise, and some 40 feet above high water, I find that a bed of dark clay comes in, underlain for about 100 yards by light-coloured sands, filled with angular blocks of clay. These blocks are mostly of small size; but they contain a flora differing markedly from that of any of the lower beds to the west. Most abundant are fragments, and even perfect leaves, of a large aroïdeous plant, of an *Araucaria* and a *Eucalyptus*; and it is remarkable that while the *Araucaria* especially has never been met with west of the pier, it is the prevailing fossil in all beds east of it. Hence to the next chine, 350 yards distant, the cliffs are almost all grit and sand, though in places near their base there is much *Teredo*-bored wood, some stems measuring 12 feet long. Beyond the chine the clays and sands are much mixed; and 300 yards beyond the chine the last beds having the appearance of fresh water origin are seen. These are a series of thin, sharply defined beds of different composition, brightly coloured, overlain by black marine sandy clay and resting upon hard white sand. They contain in several places layers of ferns, principally those with reticulated venation, belonging to *Polypodium* and *Acrostichum*. Beyond this there is a mass of sands containing broken-up leaf-beds and lignitic matter, and then the more regular sequence of the marine series. The most eastern section of the freshwater series is as follows:—

* Palæontogr. Soc. 1879, Gardner & Ettingshausen, Brit. Eocene Flora.

	ft.	in.
White sand		
Pale and dark yellow sands and whitish clay	4	6
Dark sandy clay with marine shells	6	6
Dark and bright sands	20	0
Stiff black clay	1	0
Sandy laminated clays with ferns	2	6
Mottled yellow-and-white sand	3	0
Hard white sand .... about	25	0

The cliff-sections, looked at broadly, show that the prevailing arrangement of the material is seldom departed from. Interest chiefly centres in the clays, on account of the plant-remains they contain. These may be divided by their fossils into three groups—those at the western extremity of the section mostly characterized by the presence of *Salix* and absence of palm, the central group by abundance of palms and ferns, the eastern group by *Araucaria*, net-veined ferns, and *Eucalyptus*. These differences might either be due to changes in the physical condition of the land, brought about by lapse of time between the deposition of each, or to the dissimilarity of the stations whence the respective floras were derived, or in part to both causes. The western series, as we have seen, is separated from the central group* by more than a mile of grits and clays, which cannot be traced in horizons like those east and west of it. The absence of dark clays and, indeed, of large clay patches and of distinct fossils, the coarseness and quantity of the sand and grit, the want of regularity, and the frequency with which sands and clays have been cut through and redeposited, seem to show that this was the filling-in of the former actual main channel of the river. The lenticular forms of the sands and clays in the face of the cliff show that the section must be a transverse or obliquely transverse one; and the fact that the patches which have been cut through invariably present the steep side to the west, points to the direction of the set of the stream. Thus the clays in the horizons of leaf-patches, both east and west of that which is supposed to have been at times the main channel, are seen to be much smaller and more frequently broken up and rolled into boulders as this is approached, and to be larger and therefore, at the time of deposition, more free from violent river-action as the central channel is quitted. If this was really at any time the main channel and all occupied at one time, the river must have been more than a mile in width, and the width of its valley subject to floods cannot have been less than 9 miles, and was possibly even 16 miles. The total absence of boulders and the fineness of the silt show that it flowed over a comparatively flat area; and the absence of lignite throughout a great part of its thickness, that probably there were lakes or catchment basins in its course to intercept drifting timber. Possibly the Bovey Tracey lignite basins, only 80 miles distant, which are undoubtedly of about the same age, may be relics of these. The complete absence of any material derived from flint or chalk shows that no chalk ranges were cut through by it; and the quartzose and granitic sand, and pipe-clay, that its sediment must

* Sugar-loaf to Watering Chine.

have been mainly derived from an old rock area. There are no indications of the proximity of salt water, beyond the occurrence of bored wood; and although this is met with in existing rivers even 300 miles from the sea, its presence must imply that this region was towards the lower part of the course of the river, although little influenced, I believe, by tides.

If this were admitted to be the filling-in of the main channel, the remainder of the cliff-section would have been formed in a valley not continuously subjected to the action of running water. The clay patches would mark pools or slackwater creeks; and while it is quite possible that those without fossils, and especially those that are not laminated, may have been deposited in depressions at the bottom of the river itself, it is certain that those with an abundance of leaves smoothly deposited must have been formed away from the influence of strong currents, and in sidings of, or pools left by, the river. The clays are of all shades, from white to black, the more considerable masses being always dark. The pure sediments of the river and its sands were white; and we therefore cannot but infer that the staining-matter of the dark masses was iron and carbon, derived from decaying vegetation. In the case of the leaf-beds the dark clays always have lighter layers between them and the sands which surround them, and these contain the best-preserved leaves. I have seen no instance of the dark clays enclosing lighter layers, nor of their ever, when undisturbed, coming into direct contact with the sands or grits*. The presence of leaves in the lighter beds shows at least that vegetable matter reached the pools in some abundance, and their absence in the blacker clays that they had decomposed into staining-matter. The section of the beds just west of the pier presents at its base fine river-sand, becoming carbonaceous as the current diminished, then choked with the fallen leaves, and then a nearly stagnant pool. The deposition of mud was abruptly ended by an influx of coarse grit several feet in depth. The same process was repeated in the second leaf-bed; but the third pool was formed more suddenly; for the clay rests immediately on clean grit and is not discoloured, though leaf-impressions abound in it. It is margined, like a few other leaf-beds here, with a white marl penetrated by rootlets. The succeeding 5 feet of coarse granitic grit mark the passage of a considerable body of water, and of some swiftness, and the ironstone a period of stagnation. The white clay shows that water again trickled in, charged with enough sediment to bury the leaves before they decayed. This passes gradually into the black clay, small light patches with actually skeletonized leaves in them (one has yielded a unique *Cecropia* leaf, and another a fern, *Adiantum* (*Hewardia*) *regia*) penetrating the black stagnant clay, which is dark with decomposed vegetation and charged with sulphide of iron. In some layers ferns and seeds can still be traced; but in most the vegetable matter is thoroughly decayed. Layers of compact clay are separated by what are now films of carbonaceous matter, to the number of hundreds, each layer indicating possibly only

* Dark-clay masses sometimes contain galls of the finest pipe-clay, due, I believe, to segregation.

a year. Over this is lighter clay, as if the water again began to trickle in more freely; and then once more follows the sudden change to grit. The reimbedded lumps of clay above show that many such sequences may have been broken up and swept away; indeed it is more likely that a violent flood would have this action than a preservative one.

The general dip of these strata is difficult to ascertain, owing to the absence of continuous beds *. It does not seem so uniform as in the marine series; and I am therefore only able to make a rough estimate that the western flora may be, probably, at least 200 feet vertically below the central flora. The central flora and the eastern flora must be separated by at least another 100 feet of strata, and the fern beds at the extreme east from the latter by 50 feet more. I should therefore estimate the total thickness of the freshwater beds seen in the cliff from Poole Harbour to the Meyrick Road in Bournemouth at not less than 400 feet. Nor is this the entire thickness of the group; for it seems likely, judging from the beds along its margin, that a mass of clay and sand, perhaps another 100 feet in thickness, has been denuded by the Ware in the formation of Poole Harbour. The clays in this lower part are in more extensive patches, and rarely, if ever, contain leaves, although unbored trunks of trees are not uncommon. They are evidently on a lower horizon and can be well examined in the numerous brick-pits which are worked into the hills encircling Poole Harbour from Parkestone to Upton. A well sunk at Longfleet Union Workhouse† close to Poole, penetrated 250 feet before pipe-clay was reached; but at Branksea it is much nearer the surface.

The Flora.

None of the prevailing types familiar to workers at Alum Bay are found at Bournemouth; nor are any of the well-known Bournemouth types found at Alum Bay. On the other hand, they seem to pass upward through the Marine series to the Hordwell and the Bembridge strata. They are, in many respects, identical with the types of the Bovey flora; and their affinities are completely with the floras ascribed in France to the Oligocene. The facies of the flora seems, from what is at present known of it, to be chiefly Australian and tropical American; and its forests were so varied and rich in species, that they can only be compared, among existing botanical regions, to those of Atlantic America and Manchuria. It is difficult to reconcile the prevalence of distinct leaves in each separate pool, except upon the supposition that they fell from not far distant clumps of trees. Yet we have no evidence of the close proximity of forest growths, except occasional butts of palms imbedded in clay; and the remains must have been floated down, though probably from short distances, unless, indeed, it can be supposed that they were thus separated by the different powers of flotation of the leaves.

* The dip can sometimes be seen very clearly at low water, when the beach has been removed by easterly gales.

† Proc. Geol. Soc. 1840, p. 413.

I have elsewhere endeavoured to show that there was a river of large size, bringing deposits from the westward, throughout the whole of our Eocenes. The Bournemouth Cliffs, I have long believed, present a section across its bed, and were formed during a continued period of subsidence. The sudden changes from fine to coarse sediment and the thickness of the deposit cannot be explained by the floods and freshets incidental to changing seasons, nor by the natural meanderings of a river over a wide valley, but are such as would occur whenever subsidence exceeded, in however trifling a degree, the silting-up power of the river.

A question of importance which must be raised by the floras found in these Bournemouth beds when they are studied, is whether the ages of the continental floras similar to ours have been correctly determined. While all the strata that have yielded dicotyledonous leaves or fruits in England below the Headon series are universally admitted to be Eocene, scarcely any of the beds on the continent resembling them are ascribed to that age*.

Yet the British Eocenes, exclusive of the Upper Eocenes, or Oligocenes, are known to be about 1500 feet thick, besides the great gaps in them, of which there is abundant evidence; and almost the whole of this thickness is an alternation of estuarine and fluviatile beds, rich in plant-remains from the highest deposit to the lowest.

Until recently nearly every isolated patch containing a dicotyledonous flora was supposed to be Miocene. This was due to the accidental circumstance of the Miocene formation of Œningen and other localities in Central Europe having early attracted attention and been described. As all Eocene floras approximate more or less to Miocene, it was easy, in the absence of stratigraphical evidence, to assume that all isolated patches with dicotyledons belonged to the latter period. This classification was greatly favoured by the fact that the Middle Eocene floras differ strikingly from the older ones, owing, it would seem, to the incoming of a large proportion of plants resembling existing tropical American species. The great differences seen between the older Eocene floras that were partially known (such as those of Monte Bolca, Sézanne, Sheppey, Alum Bay) and the Miocene floras further supported these views; and we accordingly find that even our own outlying patch of the Middle Bagshot series at Bovey Tracey is described as Miocene. In consequence of the position assigned to it remaining apparently undisputed, very many other formations containing similar floras have been placed in the Miocene; and had the stratigraphical evidence at Bournemouth been inconclusive, the whole of that Eocene formation must also, upon plant-evidence, have been classified as Miocene.

In the same manner the true age of the so-called Miocene forma-

* In 1874 Schimper enumerated the following ferns from beds containing dicotyledons:—

Upper Cretaceous (principally Aix-la-Chapelle)	46
Pal-eocene (Sézanne)	14
Eocene	8
Oligocene	19
Miocene	69

tions in the Arctic regions is extremely doubtful. I have long believed most of them to be Eocene; and this view is held by Dawson, Lesquereux, Saporta, Marcou, and others, all well qualified to judge. The plant-evidence is at present negative, in one sense; for although a proportion has, apparently, been identified by Heer with those of the Miocene of Switzerland, the true age of part of which is itself doubtful, another portion is identified by Dawson and Lesquereux with the undoubtedly Eocene, or even older Lower Lignitic of America. On the other hand it appears to me that the fact of there being a similarity in these floras to those of the Miocene is against their being of that age; for no two floras, so much alike and assimilating so closely to those of the present day could have grown contemporaneously in such widely separated latitudes—that is, if they grew at the same level, as is commonly assumed.

Apart from this, we have the following arguments in favour of some among the floras described being of Eocene age:—(1) the fact that the supposed Miocenes generally rest directly on the supposed Cretaceous rocks; (2) the absence of any explanation of the immense gap which Heer's grouping implies, and of which there is no stratigraphical evidence; (3) the Eocene climate may have permitted the growth of the floras, and that of the Miocene could not; (4) the probability that plants must have existed in Eocene times in the area (for there is ample evidence that it was then land), and there being no marine deposits of Eocene age there; (5) the improbability that Eocene remains can have alone escaped observation in a series of apparently consecutive deposits of immense extent and thickness, abounding in plants, and continuous, it is supposed, from the Middle Cretaceous to the Miocene.

Whether these are still called Cretaceous or Miocene, it is certain that in the various scattered dicotyledonous floras of Europe and America we have a great sequence of floras, each linked to the other by numerous plants contained in common, which there is the utmost difficulty in classifying under the existing divisions of Eocene and Miocene. Even the introduction of a Pal-eocene division and the recognition of an Oligocene formation have not lessened the difficulty. The Oligocene commences in England, as recently brought under our notice by Prof. Judd, at the base of the Headon series; but this line, unfortunately, severs in two a flora which is homogeneous, from the base of the Bournemouth beds to the Bembridge marls, and separates the lower and most important part from the congeneric and closely identical floras of France, which have all been placed in the Oligocene. Again the Lower Eocene brings together in one formation the floras of Bromley, Reading and Newhaven, and the almost perfectly distinct floras of Sheppey and Alum Bay. The Miocene, so far as its plant-beds are concerned, embraces, according to some authors, the whole Middle Eocene and up to the Pliocene, while opinions still diverge as to what are the characters by which a Cretaceous dicotyledonous flora should be recognized.

The existing divisions of the Tertiary were based, as we all know, solely upon their marine Mollusca. It would be inconvenient at

present to alter them, even were there any chance of such a proposal finding favour; but I would submit, as well worthy the consideration of this Society, whether, as the very existence of these vast series of plant-remains was unknown when the present classification was established, the time has not almost arrived to introduce a separate classification for plant-remains, which the impossibility of applying the present one to them seems to render necessary. The classification for terrestrial conditions and for marine conditions may with advantage be kept distinct until our knowledge is sufficient to enable us to correlate them satisfactorily. Otherwise it may be a very long time before confusion ceases; for I may venture to say that the flora at Bournemouth, which stratigraphical evidence of the most unequivocal description compels us to place at the very base of what is known as our Middle Eocene, would have been, if inference is permissible from their published work, regarded by Prof. Heer as Lower Miocene, by the Marquis of Saporta as Oligocene, by Baron von Ettingshausen and Prof. Lesquereux as Eocene, and, perhaps, by Prof. Newberry as Cretaceous. With less known, more isolated, and less distinctive floras the divergence of opinion would, doubtless, be greater. We have only to realize the vast difference, not only stratigraphically, but in the conditions of life upon the earth, which this discrepancy implies, to see the great inconvenience that must be caused to science through it.

Discussion.

Mr. Koch stated that the Mull beds contained leaves which very closely resembled some of Mr. Gardner's drawings.

Prof. Judd remarked that Mr. Gardner's researches pointed to the necessity for distinct classifications based on terrestrial and on marine forms respectively.

Prof. Hughes pointed out that in the case of some of the beds referred to there could be no comparison such as that suggested by Prof. Judd, as some contained remains of plants only, and no marine testaceous mollusca.

Mr. Gardner thought that the greatest separation in the Eocene formation existed between the Bracklesham and Barton series rather than between the Barton and the later series; but he thought this change was a purely local one in the British area.

2. *On the* Geology *of* Anglesey.—No. 2. By T. McKenny Hughes, M.A., F.G.S., Woodwardian Professor of Geology, Cambridge. (Read June 8, 1881.)

In a former paper on the Geology of Anglesey, which I had the honour of reading before the Society on February 25th, 1880 (Q. J. G. S. vol. xxxvi. p. 237), I endeavoured to fix the geological position of some of the sandstones and shales which overlie the granitoid, gneissic, and schistose rocks of the central axis. I gave lists of fossils and brought forward stratigraphical evidence to show that we had at the base of the series a conglomerate and grit succeeded by sandstones containing fossils which, in the present state of the grouping of those variable zones, would be referred to Tremadoc, and that these were followed in ascending order by black slates and shales, in which I found one Graptolite zone, which was referred to a known horizon in the Arenig.

I have since carried on this investigation, and have discovered other fossiliferous localities on different horizons; and having worked out the details of several of the sections, I think I have established a sequence amongst the lowest Cambrian rocks, the constant recurrence of which seems to be a strong argument in favour of its being the true order of succession of the beds; and, as a special point of interest, I can now offer conclusive evidence to prove that the quartz-jasper conglomerates are in the basement beds of the Cambrian, and not in the Pre-Cambrian series. I have had the advantage of being accompanied during part of two excursions by Dr. R. D. Roberts, and also for a few days by Mr. J. J. Harris Teall, and more recently have gone over the principal sections with Dr. Hicks.

Of Mr. Tawney's encyclopædic knowledge I have availed myself freely in every difficulty in the field and in the museum.

I use Professor Sedgwick's classification and nomenclature.

It may not be out of place to remark here that the basement beds of systems have always offered difficulties and proved a fruitful source of controversy. If part of a continental area with mountain-ranges 10,000 or 20,000 or 30,000 feet high goes down tolerably evenly, it is obvious that, before any marine beds can be formed on the highest ground, the lowest may have 10,000 or 20,000 or 30,000 feet of strata deposited over it; and the basement beds will probably vary considerably over any large area; yet there will be much in common between the shore-deposits as they creep through long ages up the slopes of the gradually submerged land. Over limited areas, however, we may expect, with very unequal thicknesses, a somewhat similar sequence in the early deposits; and if the material of which the old land is made up is of a marked character, we may find our correlation not so difficult.

That is precisely what I have to bring before the Society in this communication. We have the ridges of an old mountain land ex-

posed below the basement beds of the Cambrian; and the question is, Can we make out the succession among those basement beds so clearly that when one or two members have varied considerably from the type we start with, we still, from their position and character, can feel sure of their identification?

I propose, first of all, to describe the strata seen in some of the more important transverse sections that I have examined, and next to offer a few remarks upon the lithological character of those rocks which more immediately come within the scope of this inquiry, and of which illustrative specimens with microscope slides of some of the more important are exhibited*; and, lastly, to consider the palæontological evidence, to which I have recently made some important additions.

One of the clearest and most continuous sections is that seen in the cliff from Porth Corwg to Porthlygan on the extreme N.E. coast (fig. 1). The higher beds consist chiefly of black slate and flaggy shales with subordinate brecciated conglomerates. Of these I shall not say much, as I have not yet traced the base of the Silurian. At Trwyndu there are two ribs of felsite (2, 3 in fig. 1), and associated with them satiny slates, not unlike some of those in the gnarled series, and veined quartzose beds, all much resembling the similarly associated series of Paris Mountain.

In Porthygwichiad we have black soft slates like those which in adjoining areas are proved by fossils to be Upper Arenig. At the south end of the bay there are banded sandy flags which pass down into the brown sandstones of Penrhynglas. At their base there is another mass of black slate with scattered pebbles of quartzite, &c., some as much as 10 inches in diameter, but mostly small. These black slates are seen in the little cove south of Penrhynglas to be faulted against the gneissic series.

This section is drawn along the line of part of the Survey Section (sheet 40, section 2), and agrees with it in the general lie of the rocks.

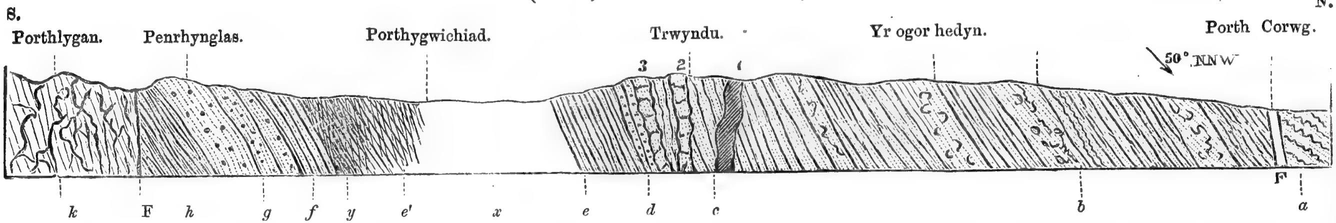
The Penrhynglas fault probably runs along the road below Rhosmannerchganol.

It is pretty clear that the black slates seen near Penrallt are thrown against the gneissic rocks of Nebo on the north by a fault which crosses the road to Tycanol south of the P in Penrallt, and crosses the road from Tynewydd to Tyddyn Mawr, south of the *r* in Penrallt. In fact all this district seems to be cut up by faults, as we might expect from what we see in Porthygwichiad, Porthlygan, and in Penrhynglas. In two quarries S.E. of Nebo, the black slates are seen thrown against and mashed into the inequalities of the Cambrian sandstone and grit, which is turned up against the southern flank of the Nebo gneiss, just as a somewhat higher part of the Cambrian series was turned up on the south side of the axis below Llysdulas. It may be by the same fault, but I did not trace it out.

In the larger quarry south of Dwyllechiad, a portion of the crushed

* These specimens are now in the Woodwardian Museum, Cambridge.

Fig. 1.—*Section along coast for $1\frac{1}{4}$ mile S. of Porth Corwg ($2\frac{1}{2}$ miles E. of Amlwch).*
(Scale, 6 inches to 1 mile.)



a. Gnarled series, greenish shale with subordinate grit and serpentinous bands, more sandy towards the base, some much gnarled, some little altered.
b. Alternations of slate and brecciated conglomerate containing quartz, quartzite, limestone, or grit, purplish-black and grey or green flaggy shale and slate, often somewhat gnarled like (*a*).
c. Grey and green darker and lighter satiny slates like some of those in the gnarled series. Some porcellanous near dykes. Dykes of diorite (1) and very veiny felstone (2 & 3).
d. Grits and slates similar to *c*.
e. Black flaggy shale.
x. Interval of low ground with nothing seen but drift; probably there are faults through here, but the soft black slates next seen on the S. in the section would rapidly weather away and leave such a hollow.
e'. Soft black slate, much crushed.
y. Broken faulty ground.
f. Banded and mottled grey and black flaggy sandy shales, passing down into
g. Brown sandstone and grit, resting on
h. Black shale with pebbles.
k. Crushed and much-veined gneissic rocks.
F. Faults.

shale in one place remains in beds parallel to the underlying grit, which is crossed by strong joints running in the same direction as the fault, so that it appears at first sight as if the shale were lying on the upturned edges of the grit. Some of this crushed mass of grit dips at a high angle, but not in that part of the section. The inference of an unconformity between the slates and gritty conglomerate near Nebo seems to be founded on a misunderstanding of these sections.

Crossing now to the south flank of the Porthlygan axis, we find that the Cambrian rocks are brought on by a tremendous fault seen in the cliff below Llysdulas, as shown in the section (fig. 2). We first have the banded flags, probably with a reversed dip; then a small fault throws the soft black slates of the Arenig against them. These, after some sharp folds, turn up again, and near a couple of dykes are found dipping in a northerly direction and sufficiently hard and compact to allow one to break lumps up in search of fossils. From these beds Dr. Roberts and I obtained a few Graptolites, which give us again our horizon and fix the beds as Arenig. These soft black shales are seen here and there along Traeth Dulas, and are succeeded near City Dulas by the banded flags with a dip of 35° N.N.E., while, near the lead-mines, brown sandstones apparently crop out from below the banded flags.

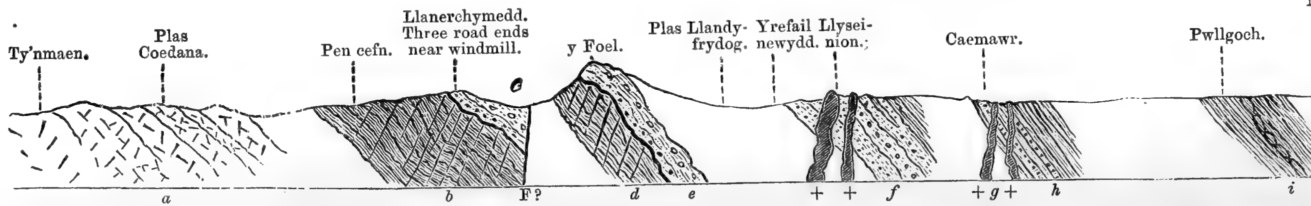
Following the strike of the beds about $\frac{3}{4}$ of a mile to the W.N.W. we have the banded flags near Ffrwd Fadoc, and again about $\frac{1}{4}$ of a mile east of Tynyffordd, and now find ourselves upon the northern flank of the Dulas Pre-Cambrian axis. The banded flags get more sandy as we descend into the series, and small openings show sandstone and grit, here and there, for a considerable distance. As they are suitable material for walling and other building, there are many places where they have been quarried; and being rocks which resist the ordinary chemical and mechanical denuding agents, they often project in bosses and ridges through the soil, showing *danedd y graig* (the teeth of the rock), as they say in Wales. These sandstones pass down into grits and conglomerates. Near Penlon a larger quarry than usual gave us an opportunity of examining the base of the Cambrian; and, when Dr. Roberts and I visited it, the face of the rock had been newly cleared, just at the junction between the conglomerate and the Pre-Cambrian. They seemed to be unconformable (as shown in the sketch, fig. 2); but of course in grits and conglomerates which are, from the nature of the case, very irregular deposits, it would not be safe to infer an unconformity from one small section. However, it is satisfactory to have what is clear from other evidence confirmed by the minor details, so far as they go. The conglomerate consists chiefly of white quartz pebbles with some quartzite and jasper and occasional fragments of schist, and is exactly like that seen in a similar position near Caernarvon.

Let us now cross the country about a mile and a half to the W.S.W., so as to get on to the black slates again, and make another traverse due S. across the lower beds of the Cambrian from an horizon determined by fossils near Caemawr, past Llanerchymedd on to the Pre-Cambrian near Ty'nmaen (fig. 3).

Fig. 2.—*Section from Penlon to Llysdulas.* (Length about 2 miles.)

a. Granitoid.
b. Grit and quartz-jasper conglomerate.
c. Banded flags.
d. Soft black shale.
F. Fault.
e. Dykes in black shale with Graptolites.
f. Banded flags; ? reverse dip.

Fig. 3.—*Section from Pwllgoch through the three road ends ½ mile E. of Llanerchymedd due S. to near Tynmaen.* (Length of section 3½ miles.)



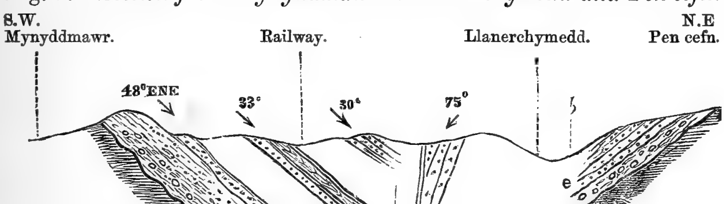
a. Finer and coarser granitoid rocks.
b. Chloritic felspathic schistose rock, weathering yellowish.
c. Conglomerate, containing quartz and fragments of underlying schistose series.
d. Yellowish-green sandy schistose rock.
e. Coarse mixed and finer quartz conglomerate.
f. Brown sandstone and shale.
h. Black shale with subordinate thin sandstones, Didymograpts, &c.
g. Flaggy shale, paler near dykes.
i. Black shivery slate with vein of ironstone.
+. Dykes.
F?. Supposed Fault.

The beds from Pwllgoch to Caemawr are probably Arenig (lowermost Bala of some). At Pwllgoch we have the ironstone so characteristic of Arenig, and at Caemawr we find Arenig Graptolites (see p. 26).

Where the dykes cross the series at Llyseinion (fig. 3), sandy beds begin to appear, and near Yr efail newydd predominate over the shales, as seen in several large quarries near the road. The low ground S.W. of this, by Plas Llandyfrydog, may be partly due to faulted broken rock; for it is probable that for every fault I have detected in this turf-covered ground I have missed 10 or may be 100.

The lowest sandstones seen pass down into the conglomerates of y Foel, E.N.E. of Llanerchymedd; and south of y Foel, apparently cropping out from below the conglomerate, there are green chloritic schistose rocks, weathering olive and brown, which are probably part of the Bangor beds (Pebidian). There is no rock exposed in the valley immediately south of this, where the word Llanerchymedd is engraved on the survey map. There is probably a fault through here, with a downthrow on the south repeating the Cambrian conglomerates, which can be traced from nearly west of Pen cefn, through the cottage near the junction of the roads from Plas Coedana and Capel Penial, and sweeping round north of the windmill, and crossing the road to Llanfihangeltre'rbeirdd obliquely, are seen, east of the farm road leading to Tyddynbach, resting with a sharp line of junction upon schists similar to those mentioned above as cropping out from below the conglomerate on y Foel (see fig. 3). Near Pen cefn the conglomerates pass up into fossiliferous flaggy grits and sandstones (see p. 25).

Fig. 4.—*Section from Mynyddmawr to Llanerchymedd and Pen cefn.*



a. Sandstone and subordinate shale.
b. Ashy-looking brecciated conglomerate.
c. Sandstone with subordinate shale.
d. Sandstone.
e. Grit with annelid-tubes.
f. Quartz-jasper conglomerate.
g. Archæan.

If we now make a traverse from near Pen cefn (mentioned above) S.W., about 1 mile to Mynyddmawr (see fig. 4), we leave the conglomerate and grit dipping westerly, and crossing the valley that runs south from Llanerchymedd, find the brown sandstones in a quarry near the *n* of Cerygydrydion dipping at about 75°, still westerly. Near Cilgwyn, however, we find ourselves on the other side of what is probably a broken synclinal, and in a quarry near

Cilgwyn see sandstones with subordinate shaly beds dipping at about 30° E.N.E. In a railway-cutting and small quarry near Cae scynan there are some ashy-looking beds of brecciated conglomerate associated with thin brown sandstones and subordinate shale. Similar beds form a ridge in the field on the west of the railway for some distance to the south. There ought to be fossils in these beds; but we only saw one undeterminable thing, found by Mr. Teall*. (See p. 26.)

Cropping out from behind these brecciated beds on the W. are the grits and conglomerates of the base of the Cambrian. In all this section the sandstones predominate over the shales. Crossing now to the west side of the Llecheynfarwy axis, we find the Cambrian rocks dipping away to the N.W., and the sequence can be clearly made out in several traverses. The Pre-Cambrian rocks consist of gneiss, which is immediately succeeded by grits, often conglomeratic; but there is no conglomerate seen so coarse as that on the other side of the axis, or on the same side of the axis further south. The grits pass up into fossiliferous sandstones, as seen near Bryngwallen, and for miles to the S.W., as indicated upon the survey map. Near the top of these sandstones there is sometimes, as near Penrhosrhyfel, a brecciated conglomerate containing small fragments of slaty and schistose rock. The sandstones are succeeded by black shales, in the lower part of which, as may be well seen along the roads by Carman and Geir, there are considerable beds of a brecciated conglomerate similar to those noted in the corresponding position east of Mynyddmawr (see fig. 4).

Thus we establish the following sequence all over the area described:—

1. Black slates, some of which must be referred to Silurian, with subordinate ash-like beds and brecciated conglomerates.

2. Black slates and shales with fine breccias and subordinate sandstones, especially in the lower part.

3. Banded flags passing down into sandstones, with subordinate shales, which become more important in some localities than in others.

4. Tough sandstones and flaggy grits, passing down into conglomerate, which varies according to the character of the underlying rocks, but in which we almost always find some bands composed chiefly of white quartz with occasional fragments of jasper, quartzite, schist, &c., and some beds of large felsite pebbles.

Sometimes the coarse conglomerate is at the bottom, sometimes the finer material forms the lower beds, and bands of coarser material occur higher up, as, indeed, is a common arrangement in all basement beds, *e.g.* Carboniferous, New Red, &c.

Petrology.

The ridge which culminates in y Foel, east of Llanerchymedd (see fig. 3), throws great light on the question of the identification of the basement beds of the Cambrian; for here we find in succession, and

* I have since found specimens of *Orthis*, probably *O. Hicksii*, in these beds.

with alternations, many of the varieties of conglomerate and grit which, even when occurring separately in other localities, we have on independent evidence referred to the same series, though differing locally according to the character of the underlying rocks, and the drift of the shingle and other circumstances.

We find here in the basement beds a coarse grit, such as is seen at Caernarvon, at Carreg goch, at Llanddeiniolen, at Bangor, on the coast east of Amlwch, and at Penlon. We have here also with the grit a quartz-jasper conglomerate, just like that seen N.E. of Twt Hill, west of Llanfaelog, and at Penlon. There is also, associated with this conglomerate and grit, a coarse mixed conglomerate made up of pebbles of quartzite, schist, rarely felsite, and various other Pre-Cambrian rocks, and approaching more closely the Bangor type of the Cambrian basement beds.

Felsites are not largely developed in the Pre-Cambrian of Anglesey, so that pebbles of that rock cannot be expected to form a large part of the overlying conglomerate, as they do from Llanddeiniolen to Bangor, where the Cambrian rocks occur on, or not far from, enormous masses of felsite.

The base of the Cambrian, near Llanerchymedd, rests on a green chloritic felspathic mudstone, often compact and hornstony, weathering olive and yellow. The character of the rock may be examined in the quarry at the junction of the two roads near the windmill. It is more blue where not weathered, with bands of lighter blue or apple-green, often showing small faults, and exactly resembling some of the banded slates of Brynian Bangor.

The microscope does not add much to our knowledge of it on the point under consideration (see Woodwardian Museum slide 248), as the fragments of this rock in the overlying series are obvious and unmistakable.

One large pebble of felsitic rock is exhibited, which I procured from the Cambrian conglomerate east of the windmill, and which must have drifted some distance; it resembles exactly a rock common among the pebbles of the Cambrian basement bed of Bangor.

Just beyond the depression which crosses the hill south of Pencefn, the granitoid series comes on. I have not observed any thing that could be referred to the Dinorwig beds (Felsitic series) in this area. The granitoid rocks are somewhat finer than that seen on Twt Hill or in the heart of the Llanfaelog axis.

About 3 miles N.N.W. of Llanerchymedd the granitoid rocks turn up again. They here consist of quartz, felspar, and often mica, are sometimes platy and schistose, and contain subordinate greenish chloritic schistose rocks and perhaps altered dykes. The Cambrian conglomerate is here composed chiefly of quartz with some fragments of jasper, mica-schists, Lydian stone, &c., and much resembles the conglomerate in the quarry between Ys cuborwen and Tygwyn, N.E. of Twt Hill (see Q. J. G. S. vol. xxxv. p. 691, f. 10), where the granitoid rock crops out immediately behind the conglomerate, though the actual junction is not seen. In microscopic structure also the Cambrian conglomerate from these two localities agrees in-

timately; while for comparison with the finer and more compact quartz-conglomerate of the Field quarry, Twt Hill (Q. J. G. S. vol. xxxv. Nov. 1879, p. 683, f. 2), I rather refer to a quartz-conglomerate much higher up in the Cambrian, which occurs on the shore S.W. of Garth Point, Bangor, near where the great cloaca opens on the Straits (Woodwardian Museum slide 217). S.W. of Llanerchymedd, near Bryngwallen, the Pre-Cambrian rocks consist of a variable gneissic series, and the Cambrian basement beds are finer and composed chiefly of quartz. They can be well studied in a quarry in the field, on the north side of the road, below the *g* of Bryngwallen, while the gneiss is exposed along the road, and in one place a quarry is opened in it.

In the quarry on the north of the road the Cambrian conglomerate is thin and irregular. It resembles much the conglomerate of Twt Hill, both in the mass and under the microscope (see W. M. slides Nos. 214, 215). It is seen to pass into an altered and veiny grit, portions of which are crushed; but in the weathered portions there are traces of fossils. The slice exhibited (W. M. slide 215) is cut across the cast of an *Orthis*.

The sandstones and grits of the Cambrian of this district show nothing peculiar in their composition, and do not differ much from one another, except in the amount of felspathic matter in the matrix. Even where the fragments are not large enough to be seen with the naked eye, the presence of any considerable quantity can generally be detected at once in the field by the dull yellow of the weathered portions and the manner in which the whole mass of rock breaks up and yields to atmospheric agencies.

Where they are composed entirely of quartz and have been much crushed, and veining has supervened, we have, of course, every stage from sandstone or grit to white quartz. Examples of this may be seen in the three specimens exhibited from the same mass at Bryngwallen: (19) is much crushed; (20) is compact, uncrushed, and not weathered; (21 and corresponding slides, Nos. 214, 215, and 222) is weathered and contains fossils.

As to the shales there is no question, and therefore I need not refer to them under this head.

The brecciated conglomerates vary considerably in the upper part of the black shales; they are often very coarse. Their ash-like appearance is often increased by the rust-lined cavities from which bits of earthy iron-ore or pyrites have perished under the action of weathering. The scattered fragments in the highest rocks of this character seen in Porth Corwg consist of limestone, quartzite, grit, purplish, black, and grey slate, quartz, &c.; lower down, the slaty fragments predominate.

In the brecciated beds near the base of the shales, on both sides of the Llecheynfarwy axis, S.W. of Llanerchymedd, the fragments are not so much scattered through the mass, but form a compact breccia of small pieces, chiefly of slate.

In the Bangor-Caernarvon district the drifting of the shingle which formed the shore-deposits of the Cambrian sea was from S.W. to

N.E.; and so, as we have the granitoid rocks at the S.W. end only, we find the basement bed there is either a kind of arkose or chiefly composed of quartz with a few pieces of mica-schist and jasper. As we follow it 4 or 5 miles to the N.E., the quartz has got pounded into small grains, giving the grit of Carreg goch and Llanddeiniolen, where the grit contains much felspathic material and is overlain by a coarse conglomerate of pebbles of the felsite which here formed the shore; and further on, towards Bangor, fragments of the still higher Bangor volcanic series helped to make up the Cambrian shingle-beach.

Fragments of vein-quartz and quartzite from the Pre-Cambrian occur scattered through the basement beds everywhere; but the grit is perhaps derived largely from the imperfect crystals of the Dimetian.

On the N.W. side of the Anglesey central axis, which consists of various gneissic rocks (Dimetian in part) and a felspathic mudstone (Pebidian), the Cambrian basement bed varies accordingly, and is generally more quartzose. Near Penlon, where it rests on quartz-felspar rock, it consists chiefly of quartz, and exactly resembles the Twt-Hill conglomerate. Near Llanerchymedd, where there is a mass of greenish schistose rock succeeding the Dimetian, the Cambrian basement bed contains a large quantity of fragments of that rock, certain bands being chiefly composed of it. Near Bryngwallen, where the underlying Archæan consists of gneissic rocks, the Cambrian basement beds are made up of grit and quartz conglomerate in lithological character exactly like that of Twt Hill, but here fortunately fossiliferous.

If we follow the basement beds to the S.W. we find a much greater mixture of rocks in the conglomerate, until among the bosses of rock in the sand dunes north of Cymmeran Bay we see evidence of the existence of newer Pre-Cambrian beds than are now exposed anywhere in that neighbourhood.

Thus along the N.W. flank of the Anglesey Pre-Cambrian axis we have the same variation in the lithological character of the Cambrian basement beds as we have along the S.E. flank of the Bangor-Caernarvon axis; here a fine quartz conglomerate or grit, and there a coarse shingle, composed of large pebbles of felspathic rocks and rough quartzite according to drift of the shore-currents and the material of the older rocks from which each particular part of the conglomerate was derived.

Palæontology.

The lowest horizon at which I have yet found fossils in Anglesey is in the flaggy grit associated with the basement conglomerate near Pen cefn south of Llanerchymedd. From these beds I have procured slabs with obscure fucoidal markings and very distinct Annelid tracks nearly a foot in length.

Further to the S.W., near Bryngwallen, in beds immediately succeeding the conglomerate, the *Orthis*, mentioned in my previous paper (Q. J. G. S. vol. xxxvi. p. 238, May 1880), first appears. I

referred it to *O. Carausii*, an Arenig or Tremadoc fossil; but as I think I can show that *O. Carausii* and *O. Hicksii* are the same species, under the latter name we have it recorded from the Menevian.

These species both belong to the *O.-Actoniæ* group, differing from the *O.-calligramma* group in the relative shallowness of the dorsal valve, being almost plano-convex, and from the *O.-flabellulum* type in having the ventral valve the more convex. It will be observed from the descriptions in Davidson that the two species agree in every particular till we come to the absolute size, the relative length and width, and the number and arrangement of the ribs. From the specimens exhibited it will be seen that the relation of length to width is not constant, that the size is a question of age, and also that, in respect of the number and arrangement of ribs, every intermediate form between *O. Hicksii* and *O. Carausii* is represented in the specimens procured from one and the same bed in Anglesey; therefore we must put this down as an early form of *Orthis* following the receding shore in Cambrian times through the long ages that elapsed between the deposition of the rocks known as Menevian and that of the beds called Arenig.

The *Neseuretus* previously recorded (Q. J. G. S. vol. xxxvi., May 1880, p. 238) is probably from a slightly higher horizon, about 2 miles to the S.W., where the *Orthis* also is abundant.

In some ash-like beds at the base of the black shales east of Mynyddmawr, near Llanerchymedd, a curious fossil was found by Mr. Teall. It looks like a *Conularia*, around which there was something of a nodular form which has perished, leaving only a large cavity showing no markings on the outside. The quadrangular central portion is furrowed longitudinally and, especially near the thicker end, shows a cross platy arrangement. This last feature is probably, as it stands, due to mineralization, but, it may be, following organic structure. The form of the whole fossil certainly suggests an organic origin*.

In a quarry by Caemawr, 1½ mile north of Llanerchymedd (see fig. 3), there is a black shale in which Graptolites are tolerably abundant along certain bands.

The forms which Dr. Roberts and I found are all referred by Professor Lapworth to

Didymograptus Murchisoni, *Beck.*

In the black slates tangled among the dykes on the N.E. coast, S.E. of Llysdulas, we found a few Graptolites, which are, according to Professor Lapworth,

1. Climacograptus cœlatus, *Lapw.*
2. C. bicornis?, *Hall.*
3. C. —?, sp. nov.

The last two are not sufficiently well preserved to allow of certain determination; and Professor Lapworth says that No. 2 may be *C. cœlatus*, and No. 3 may be only a stem of *Dicranograptus*, sp.

It is worth observing that whereas dykes usually interfere with the fossil-collector, in Anglesey they often help; for the black slates

* See p. 22, footnote.

and shales are so rotten that it is almost impossible to examine them except where a little baked and caked by the metamorphic action.

I take it that the Graptolite-bearing beds of Caemawr and Llysdulas, and those of Llangwyllog, described in my former paper, all belong to the same series and are of about the same age as the beds of Pontseiont, south of Caernarvon, described by Mr. Marr (Q. J. G. S. vol. xxxii. p. 134), and as the beds in the south arm of Abereiddy Bay, and that we had better call them all Arenig for the present.

The highest horizon in the black slates from which I have procured any fossils is in the black slates between the two great felsite ribs in the Mona mines of Paris Mountain, where, after we had searched for some time and found only a few obscure traces, Mr. Fanning Evans, whose kind assistance I take this opportunity of acknowledging, had the good luck to pick up a slab which has yielded no less than eight species, viz.:—

Rastrites (Monograptus) triangulatus, *Harkn.*
Monograptus gregarius, *Lapw.*
—— attenuatus, *Hopk.*
Diplograptus tamariscus, *Nich.*
—— acuminatus, *Nich.*
—— modestus, *Lapw.*
Climacograptus rectangularis, *M'Coy.*
—— normalis, *Lapw.*

Professor Lapworth, who determined these for me, considers that they indicate an horizon equivalent to the *M. gregarius* zone of the Birkhill shales or the lowest zone of the Graptolitic mudstone of the Lake District, *i. e.* distinctly Silurian.

It would appear therefore that we have in Anglesey:—

1. An upper slate group, in which I have fixed two life-zones, which must be referred to the Silurian, of the boundaries and subdivisions of which I hope hereafter to offer the Society further details.

2. A lower group of slates and shales in which Arenig fossils have been found in several localities, and in which, after correcting the determination of a species of *Orthis*, we have reason to suspect that Tremadoc and even Menevian beds may be recognized; and below these are

3. The basement beds of the Cambrian, consisting of conglomerates, grits, and sandstones, of which this paper chiefly treats.

Speaking generally on the correlation of the beds, I think we have in this Anglesey section an approach to the Scandinavian type; in both there is a thinning out of the lower groups (the Harlech, Menevian, and Lingula Flags) against an old shore-line; but certain forms of life which, when the older rocks are well developed, have not been found so low down, here occur near the bottom of the local series. A conglomerate passing up into fucoidal sandstone forms our base; but above that the first life-zone is represented as yet by only two species, of one of which, the Trilobite, only a fragment of one individual has yet been found, while the other I have shown above is a doubtful species. The next two life-zones are both Arenig. Above this nothing is clear till we reach the Silurian.

Discussion.

Dr. Roberts drew attention to the fact that in Anglesey the basement conglomerate was composed of quartz pebbles, while in the Bangor district it consisted of felsite pebbles. The Twt-Hill conglomerate at Caernarvon exactly resembles that in Anglesey, and, like it, rests on the granitoid axis. If the Anglesey conglomerate was the Cambrian conglomerate, it was extremely probable that the Twt-Hill conglomerate was of the same age.

Dr. Hicks agreed with Prof. Hughes in regarding the rocks referred to in Anglesey as forming the base of the Cambrian, and as being entirely distinct from the Pre-Cambrian. The pebbles and matrix of the conglomerates varied with the rocks upon which they reposed, and from which they must have been chiefly derived. The mistake made in associating them with the Pre-Cambrian was due to a want of the recognition of this fact. He had examined these sections and also the one at Twt Hill recently, and he believed that the interpretations given by Prof. Hughes and Dr. Roberts were correct.

3. *On some* NEW *or* LITTLE-KNOWN JURASSIC CRINOIDS. By P. HERBERT CARPENTER, Esq., M.A., Assistant-Master at Eton College. (Read December 7, 1881.)

[PLATE I.]

I. THE LANSDOWN ENCRINITE.

MILLERICRINUS PRATTII, Gray, sp.

1828. *Encrinites* (*Apiocrinites*) *Prattii,* Gray, Phil. Mag. vol. iv. p. 219.
1833. *The Lansdown Encrinite,* Jelly, Bath and Bristol Mag. vol. ii. p. 36.
1833. *Apiocrinites obconicus,* Goldfuss, Petref. Germ. Band i. p. 187, Taf. lvii. fig. 5.
1834. *Apiocrinus obconicus,* Fischer, Bibl. Palæont. Anim. p. 319.
1840. *Millericrinus obconicus,* D'Orbigny, Hist. Nat. des Crinoïdes vivans et fossiles, p. 80, pl. xiv. figs. 23–28.
1848. *Millericrinus Pratti,* Bronn, Index Palæontol. p. 729.
1854. *Apiocrinus Prattii,* Morris, Cat. Brit. Foss. 2nd ed. p. 72.

The fine collection of Oolitic fossils which was made by the late Mr. William Walton, of Bath, and was purchased some years ago by the University of Cambridge, contains a very remarkable series of specimens of a Crinoid from the Great Oolite of Lansdown, a well-known hill at Bath. Its occurrence seems to have been first recorded (though not first noted) in the year 1828 by the late Dr. J. E. Gray*, who made a curious error with regard to its geological horizon, stating it to have been found in the Lias. He named the type *Apiocrinites Prattii,* and described it as intermediate in character between the *A. ellipticus* and *A. rotundus* of Miller.

Some years after the publication (1821) of the well-known work on Crinoids by the last-named author, some specimens of this species were shown to him by the Rev. H. Jelly, who states that Miller "was unable to satisfy his own mind as to their true nature and history." In the year 1833 a semipopular illustrated account of these fossils was published by Mr. Jelly†, and about the same time they were redescribed by Goldfuss‡, with the aid of some excellent figures, under the name of *A. obconicus.* He had, however, a smaller series of specimens than those at Jelly's disposal, some of which now form

* "Description of a new kind of Pear-Encrinite found in England," Phil. Mag. vol. iv. pp. 219, 220.

† "The Lansdown Encrinite," Bath and Bristol Mag. no. 5, vol. ii. January 1833, pp. 36–47.

‡ Petref. Germ. Bd. i. p. 187, Taf. lvii. fig. 5.

part of the Walton collection; and the great peculiarity of the type, viz. the very variable length of the stem, which had been previously noted by Jelly, did not attract his attention. But he pointed out that the remarkable shortness of the stem, of which he gave a good figure, is a character which sharply distinguishes this species from the other *Apiocrinites.*

Both Jelly and Goldfuss drew attention to what they regarded as pores in the calyx, one being situated immediately beneath the centre of each first radial (Pl. I. figs. 13, 21). They spoke of them as similar to the pores described by Miller in *Apiocrinus rotundus*; and the first-mentioned writer pointed out that "they are generally closed with a small plate or plug, as it were." The same peculiarity was noted by D'Orbigny*, who transferred this type amongst others to his new genus *Millericrinus,* but retained for it Goldfuss's specific name, *obconicus.* According to him, "Par sa forme conique, par l'irrégularité de ses pièces basales, par le pore ou la pièce accessoire de celles-ci, le *M. obconicus* se distingue nettement des autres espèces; il diffère encore par son sommet, auquel participent plusieurs articles de la tige." D'Orbigny, like Goldfuss, received specimens from Miller, some of which he figured; but they were not sufficiently varied in character for him to detect the most striking peculiarity of the type.

In Bronn's 'Index Palæontologicus,' Gray's specific name is appended to D'Orbigny's genus; but a few years later the name *Apiocrinus* reappears in Prof. Morris' 'Catalogue of British Fossils.' In no publication of a later date than this have I been able to find any mention of the type. It does not appear in any lists of Great Oolite fossils with which I am acquainted, and seems to be somewhat of a rarity, as but little quarrying is now done on Lansdown; and I was informed by the late Mr. Charles Moore, F.G.S., that he had met with no traces of the fossil during forty years of collecting in that neighbourhood. There are, however, a few good specimens in other collections than that made by Mr. Walton, *e. g.* in that of Dr. T. Wright, F.R.S.; and I learn from my friend Prof. Sollas that there are some fine slabs in the Bristol Museum from the Lansdown quarries, which contain the remains of several individuals and bear the MS. name *Gnathocrinus fusiformis,* Austin. The national collection at South Kensington also contains a few examples of this type, including the original of Gray's description of it.

In many cases these *Millericrinus* remains are closely intermingled with those of a fine *Pentacrinus,* as on the slab mentioned by Mr. Jelly. They may at once be distinguished by their ten simple arms, those of the *Pentacrinus* forking once or oftener.

The series in the Walton collection is not distinguished by the presence of any especially well-preserved specimen with long arms and pinnules, such as one frequently meets with among the Pentacrinites; but it is of unusual interest to the morphological palæontologist, as it contains so many individuals presenting remarkable

* 'Hist. Nat. des Crinoïdes vivans et fossiles,' Paris, 1840, p. 80, pl. xiv. figs. 23–28.

structural peculiarities, and I feel proportionately grateful to Prof. Hughes for his kindness in entrusting it to me for description.

1. *The Stem.*

a. *Variation in its length and in the number of its component joints.*

The longest stem which I have met with in any individual is that represented in Pl. I. fig. 14. It is rather more than 50 mm. in length, and consists of about 70 joints of a discoidal shape with denticulated edges. They are all of about the same height, a few here and there being slightly thinner than the rest. The uppermost one is but little thicker than those below it, and is of the same shape as in all Apiocrinidæ, its ventral surface being divided into hollows for the reception of the basals by five prominent radial ridges. This is indicated on the outside of the calyx by the upper edge of the top stem-joint presenting an alternation of elevations and depressions. The former, radial in position, are the ends of the ridges, while the latter mark the synosteal surfaces for the attachment of the basals (Pl. I. fig. 12). The stem tapers gradually to about the 30th joint from the top, below which it is tolerably uniform. Its lower end is unfortunately broken away, but the lowest portion of what remains seems to be covered with a kind of incrustation that obscures the lines of suture of the last six or eight joints.

A very different stem is represented in Pl. I. fig. 6. It is little more than half as long (27 mm.) as that just described, but has nearly as many (about 60) joints. It is broken below, but the lowest part remaining shows a slight tendency to a beaded appearance; for it consists of about 25 narrow but thick joints, which increase very slightly in width from below upwards, and together make up more than half of the whole length of the stem. The joints immediately above these begin rather suddenly to decrease in thickness, but at the same time increase in width, so that the upper part of the stem tapers rather rapidly from above downwards. The uppermost joints are very short and closely set, and that just under the calyx is of the usual shape, the radial ridges being a trifle larger than in the last-mentioned specimen.

Another individual (Pl. I. fig. 8) has a stem 25 mm. long, and generally similar to that shown in fig. 6, though somewhat different in details. It consists of about 50 joints, the uppermost of which are the thickest, while the rest decrease rather rapidly from above downwards; but in the lower part of the stem the joints again increase in thickness as if it were going to become beaded. The last ones, however, seem to have fused into an irregular slightly swollen mass, on which their sutures are somewhat obscured. The same peculiarity is visible in the stem-fragment represented in Pl. I. fig. 5, which is not only swollen but seems to have a branch (root?) proceeding from it as in some *Apiocrinus*-stems.

In another case (Pl. I. fig. 7) the stem, which measures 23 mm. in length, tapers downwards rather rapidly at first, but afterwards

more slowly. Except for some irregularities to be noticed hereafter, all the joints to just above the lower end are wide and tolerably thick disks. The last two are so closely united that the suture between them is scarcely visible; and the under surface of the lowest joint is rounded off without any trace of striations, while its central opening, which is at the bottom of a shallow pit, is closed up. Whether it was open or not throughout life must of course remain uncertain, just as in the case of *Comatulæ* with more or less marked pits on the lower surface of the centrodorsal. The same remark applies to two other stems (Pl. I. figs. 11, 12). One is 17 mm. long, and consists of about 16 rather thick joints, the lowest of which is rounded off, while the other is but 10 mm. long and is composed of 15 joints. In another specimen, on the other hand, the stem, though containing 20 joints, is only 8 mm. long. Other instances are (1) stem of 9 joints, $8\frac{1}{2}$ mm. long; (2) stem of 7 joints, $6\frac{1}{2}$ mm. long (Pl. I. fig. 1), both of them rounded off below.

The next specimen to be considered (Pl. I. fig. 13) is one with a short conical stem, 4 mm. in length and composed of 5 joints, the lowest of which is quite small and rounded off without any trace of a central perforation. This leads us to a couple of individuals (Pl. I. figs. 2, 23) that might readily be mistaken for cirrhus-less *Comatulæ*, all that represents the stem being a couple of flattened joints situated beneath the basals and closing in the calyx below. Fig. 18 shows that even one of these may be absent, the basals resting on a slightly convex pentagonal plate without any central perforation. It is very interesting to compare this figure with fig. 22, which represents the concave striated facet on the under surface of the top stem-joint of a stalked individual. The two or three joints immediately below the uppermost one present differences of a similar kind, according as they belong to individuals with quite short or with longer stems. In the former case (Pl. I. figs. 3, 17, 20 *b*) their under surface is concave, perforate, and striated; but if they be the lowest joints of the short stems (Pl. I. figs. 2, 4, 13, 23) they are imperforate, rounded off below, and exhibit no indications of striation.

Here, then, within the limits of what is obviously but a single species, we meet with a most remarkable series of transitions from the pedunculate to the free mode of existence. But the difference between the two is of less physiological importance than it was formerly considered to be. For some *Pentacrinus*-species, although stalked and attached when young, seem when mature to be practically free in their mode of life, while others are fixed by a slightly spreading base*. Such a "free" *Pentacrinus* is *P. Wyville-Thomsoni*†, and, according to de Loriol‡, the fossil *P. briareus* and its allies led a similar independent existence; but in both these cases the portion of stem which remains in connexion with the

* Bull. Mus. Comp. Zool. vol. v. no. 14, p. 296.

† The Depths of the Sea, p. 444.

‡ Notice sur le *Pentacrinus* de Sennecey-le-Grand, Chalon-sur-Saone, 1878, p. 12.

calyx retains its cirrhi. In the Lansdown Encrinite, however, there are none of these organs upon the stem; and the evidence as to the presence of a root is very incomplete. The short-stemmed forms (Pl. I. figs. 2, 4, 10–13, 23), at any rate, must have been more "free" than most *Comatulæ,* though they find a parallel among those species, such as *Actinometra Jukesii,* in which the cirrhi entirely disappear from the centrodorsal when maturity is reached*.

There are other types among the Pelmatozoa which, although stalked, seem to have been practically free in their mode of life, e. g. *Woodocrinus*, *Glyptocystites*, and some (all ?) species of *Pentremites.* In all of these the stem tapers downwards to a point and bears few or no cirrhi. Hence the distinction between the stalked types and those which merely retain the top stem-joint, though of considerable morphological importance, does not necessarily involve corresponding physiological differences.

b. *The intercalated Stem-joints.*

Several individuals (Pl. I. figs. 1, 7, 10) have small incomplete lenticular joints intercalated among the larger stem-joints. This peculiarity has been noted by de Loriol in other species of *Millericrinus* and also of *Apiocrinus*, some of which he has figured†. The lenticular joints were regarded by him, rightly, as I believe, as new joints in process of formation. Quenstedt‡, however, who has met with the same peculiarity in *Pentacrinus*, speaks of it as a "kleine Missbildung." The peculiarities of the sixth and subjacent joints of the individual represented in fig. 7 seem to represent the later stages of this intercalation of new joints.

c. *The top Stem-joint.*

It has been already mentioned that the top stem-joint is somewhat variable in its appearance. It is sometimes relatively thick and almost uniformly so all round (Pl. I. figs. 1, 3, 4, 13); while it is sometimes comparatively thin immediately beneath the basals, with a strong ascending process between the lower angles of every pair (figs. 6–8, 10, 12). Judging from what is shown in the original of fig. 21, I cannot help suspecting that the appearance of large upper stem-joints may sometimes be a secondary condition. On one side of this specimen two large stem-joints are visible just below the basals; but they are broken away on the other side, and it then becomes manifest that they enclose a central core of much thinner and narrower joints, which seem to extend upwards to the basals and to have been continuous with those lower down the stem. There appears therefore to have been a secondary deposit of lime-

* Proc. Roy. Soc. 1879, no. 194, p. 390.

† "Monographie des Crinoïdes fossiles de la Suisse," Mém. de la Soc. Pal. Suisse, 1877–79, pp. 40, 42, 82, 94, pl. v. fig. 9, pl. vi. fig. 7, pl. vii. fig. 2, pl. xi. fig. 21, pl. xii. fig. 27.

‡ 'Petrefactenkunde Deutschlands,' Bd. iv., Asteriden und Encriniden, p. 247, Taf. 98. fig. 118, Taf. 99. fig. 44.

stone outside the upper stem-joints, which divided up into segments not corresponding with those enclosed by it.

On the other hand, the appearance of some individuals would lead one to suppose that the uniformity and relative thickness of the top stem-joint are the signs of its age, and that this condition may be replaced by one in which this joint is thinner and unequally developed, the change being due to the intercalation of a new joint immediately beneath the basals. At any rate that is the manner in which I should interpret the peculiarities of the specimens shown in figs. 11, 17, & 20 *b*. Judging from the two former only, one would almost say that this was a type with a dicyclic base like *Encrinus*; but the latter shows that the apparent underbasals are really the disconnected portions of a new top stem-joint.

2. *The Basals.*

The basals are pentagonal plates with tolerably open upper angles, and not quite twice as wide as they are high. As a general rule they form a closed circlet, completely separating the radials from the top stem-joint (Pl. I. figs. 1, 4 *b*, 6–8, 10, 14). The under-surface of this basal circlet is deeply concave, and marked with very distinct radiating striæ around its margin (fig. 16). There are, however, many and various irregularities in the structure of the base. Thus in one individual three of the basals on one side of the calyx are of the ordinary character; but on the other side one of the radials is greatly developed and is in contact with the top stem-joint for nearly the whole of its width, while the radial next it is also larger than usual, so that the two basals beneath them meet neither one another nor their fellows.

Instead of the basals being in complete contact with one another all round, they are sometimes separated more or less completely by small irregular intermediate plates (Pl. I. figs. 3, 23), while between them and the radials the supposed "ovarial openings" are sometimes visible, as already mentioned. These were first noticed in *Apiocrinus rotundus* by Miller*, who speaks of "more or less elevated tubercles having a central perforation, which, in one instance, I have traced to pass through the joint of the pelvis into the space between it and the costal joints, extending perhaps thence into the funnel-shaped [visceral] cavity. This has suggested to me the idea that it might have led to an ovary having five ducts, somewhat similar to that of the *Echinus*." According to Jelly†, these openings are frequently almost imperceptible in *Ap. rotundus*, "whereas in this fossil [*M. Prattii*] they occupy a very considerable place in its external configuration. Besides this, they are, almost without exception, closed with a small plate or plug, as it were; and this is sometimes, though rarely, punctured in the centre." Goldfuss‡ speaks of finding between the radials of one individual "einen Kanal, der zur Leibeshöhlung führt;" while, according to d'Orbigny §, the

* A Natural History of the Crinoidea, p. 31.
† *Loc. cit.* p. 9 of separate copy.
‡ *Op. cit.* p. 187.
§ *Op. cit.* p. 80.

basals are "toujours pourvues à leur angle latéral supérieur, ou d'un pore très marqué, ou d'une petite pièce ronde ou irrégulière; angle supérieur plus ou moins ouvert suivant les individus, ou même sur les pièces d'un même sommet, partie inférieure droite ou arquée, partie latérale échancrée par le pore ou la petite pièce."

Many specimens, it is true, have a deepish pit in the middle of the lower edge of each radial (Pl. I. fig. 17); but this is frequently absent altogether (fig. 4 *b*), and when present certainly does not lead into the interior of the calyx. It is not unfrequently occupied by a small plate or tubercle, which may or may not be in contact below with one of the accessory basal pieces (fig. 13). In none of the specimens that I have seen has this plate any central pit, such as was described by Miller and Jelly. I can form no idea as to the meaning of these accessory plates: they are evidently without any morphological importance, or they would be more constant in their occurrence.

3. *The Radials.*

As in the other Neocrinoidea there are usually three radials in *M. Prattii*, the last of which is an axillary. But in two specimens in the Walton collection the number is increased to four. In one case the lowest of the four is much smaller than the other first radials; but in the individual which has two rays of four joints each, the two lowest, or first and second radials, are of the usual size, and a short but wide joint is intercalated beneath each of the axillaries (fig. 23).

The general aspect of the calyx when viewed either from the side or from above (Pl. I. figs. 11, 17, 20, 21), is exceedingly pentacrinoid, the articular faces of the radials sloping more steeply and being better developed than they are in most species of *Millericrinus*. They are trapezoidal in shape, somewhat wider than high, and crossed, rather below the middle, by a strong articular ridge. Immediately beneath the centre of this ridge, which expands considerably around the opening of the axial canal, is a deep pit for the insertion of the dorsal elastic ligament. The muscle-plates are large and well marked, and are separated by a rather wide notch; they are bounded below by slight horizontal ridges which divide the muscular fossæ from those for the insertion of the interarticular ligaments.

The distal faces of the second radials are very different from those of the first, as is the case in most of the Neocrinoidea. The union between them and their successors is effected merely by ligaments, without the intervention of the muscles which take part in most of the articulations between the successive arm-joints. There is a strong articular ridge (Pl. I. fig. 15) which is pierced by the opening of the central canal, and decreases in width from above downwards. On either side of it is a deep fossa which lodged the interarticular ligament. There was therefore no possibility of any thing but a lateral movement between these two joints. The pecu-

liarity of this mode of articulation was first noticed by J. Müller*, who described it as occurring in *Pentacrinus caput-Medusæ* and in the *Comatulæ*, and remarked that it had been previously figured by Goldfuss in *P. briareus*; while he gave the name "syzyzy" to an immovable sutural union of two joints such as occurs between the original third and fourth brachials of most *Comatulæ*. These become ultimately united into one double joint, the outer half of which bears a pinnule; and similar syzyzial unions occur at longer or shorter intervals throughout the whole length of the arms. De Loriol† has somewhat unfortunately employed the name "syzyzy" for the form of ligamentous articulation upon a vertical ridge which occurs between the second and third radials of most Neocrinoidea (Pl. I. fig. 15), and speaks of the distal face of the second radial as presenting a "facette articulaire syzygale;" though the second epithet, understood in its original sense, implies the absence of any articulation‡.

4. *The Arms.*

As is almost invariably the rule among the Neocrinoidea, the articulation between the first and second brachials of *M. Prattii* is a ligamentous one, like that between the second and third radials. Quenstedt's figures (Encriniden, tab. 103) show that the rule holds good in *M. mespiliformis*, and I have found the same to be the case in *Ap. Parkinsoni*.

The position of the first syzygial or double joint in the arms of *M. Prattii* appears to vary from the third to the fifth brachial, and not to have the constancy which is met with among the *Comatulæ*.

* "Ueber den Bau des *Pentacrinus caput-Medusæ*," Abhandl. d. Berlin. Akad. 1843, p. 26 (of separate copy).

† *Op. cit.* pp. 257, 258.

‡ In a previous paper (this Journ. vol. xxxvii. p. 134) I have pointed out that it is a mistake to suppose that *Millericrinus* differs from *Apiocrinus* in the presence of an articular facet on the first radials, for traces of a transverse articular ridge and of muscle- and ligament-fossæ can be made out on the central ends of the first radials in good specimens of *Apiocrinus*. I had not at that time seen any well-preserved calyx of *A. Parkinsoni*, and, judging from d'Orbigny's figure (pl. 5. fig. 6), was led to imagine that in that species the first two radials are united by syzygy, as is generally supposed. Recently, however, I have been permitted to examine the excellent calices of that species in the Museum of Practical Geology, and I find that it too had a muscular articulation between the first two radials. I suspect the same to be the case in all Apiocrinites. The power of movement, however, must have been excessively limited, and the presence of the enormous fossa beneath the transverse articular ridge distinguishes this form of articulation from that met with in most Neocrinoidea, though an approach to it occurs in some species of *Millericrinus*.

I may also state here that the second and third radials of *Ap. Parkinsoni* and of *Ap. Meriani* (as I learn from specimens kindly lent me by M. de Loriol) are united by ligamentous articulation, just as described above in *M. Prattii*, though the lower end of the vertical articular ridge in the *Apiocrinus*-radials is separated from the dorsal edge of the plate by a large fossa similar to that on the first radials, and either absent or but poorly developed in *Millericrinus*.

It will be evident from these considerations that *Apiocrinus* conforms more closely to the type of *Pentacrinus* and *Comatula* than has been hitherto supposed, though the enormous expansion of the calyx-plates marks it off very distinctly from the other Neocrinoidea.

The next syzygy is equally variable in position, following the first at an interval of from 0–3 joints. The syzygial faces are marked with well-defined radiating striæ, just as in the *Comatulæ*.

The arm-joints are short and nearly oblong in outline, bearing pinnules alternately upon opposite sides, the first pinnule being borne by the second brachial, which is slightly more wedge-shaped than the nearly rhomboidal first brachial. In one or two pinnules of the specimen represented in fig. 9 the side-plates of the ambulacra are still visible; they are generally similar to those of many recent species of *Pentacrinus* and *Comatula*, though somewhat more massive, as they are in various Palæocrinoids.

5. *Remarks.*

The species which most nearly resemble *M. Prattii* are *M. Nodotianus*, d'Orb., and the small variety of *M. Munsterianus*, to which the name *Buchianus* has been given*. But in both species the radials are relatively wider and less steeply inclined than those of *M. Prattii*. This is more especially the case in *M. Nodotianus*, which species is also distinguished by the stem-joints having a tendency to the petaloid markings that are characteristic of the Pentacrinidæ.

A possible ally of *M. Prattii* is the singular type described by Quenstedt† as a *Pentacrinus* from the White Jura, γ, of Sotzenhausen. It has no sign of any verticils of cirrhi on the stem, and the number of arms was very probably limited to ten, as the few that are preserved do not fork as far as the tenth brachial, though they may of course have done so on a later joint, as in *P. briareus*. Quenstedt says nothing about the surfaces of the stem-joints; but it is difficult to see why the type should be referred to *Pentacrinus* rather than to *Millericrinus*, the former genus being especially distinguished by the presence of cirrhus-verticils on the stem.

Among the various types of *Pentacrinus* the calices of which are known, that which most closely resembles *M. Prattii* in the characters of its calyx is the recent *P. Wyville-Thomsoni* from the North Atlantic‡. The radials and basals are about the same relative size in both cases, and the markings and slope of the articular faces are very similar, the curious concentric lines on the muscle-plates of the *Pentacrinus* occurring also on those of the *Millericrinus* (Pl. I. figs. 11, 13, 17, 20, 21). The ventral aspect of the calyx, with its tolerably wide central funnel, is also very much the same in both cases, that of the *Millericrinus* being rather the flatter. But this resemblance disappears when the two calices are viewed from below. In the *Pentacrinus* the facet which receives the top stem-joint and is formed by the undersurfaces of the basals is relatively small, and the petaloid markings of the *Pentacrinus*-stem begin to be visible upon it. This facet is relatively

* De Loriol, *op. cit.* pp. 35–39, pl. 7. fig. 14.

† *Op. cit.* tab. 99. fig. 174.

‡ Journ. Linn. Soc., Zool. vol. xv. pl. 2. fig. 23.

much larger in *M. Prattii* (Pl. I. fig. 16), and its edge exhibits the same radial striation as is to be found on the faces of the stem-joints themselves (Pl. I. fig. 22).

6. *Localities and Horizon.*

Nearly all the specimens of this fossil which are preserved in collections are from the Great Oolite of Lansdown. I learn from Dr. Wright that it is a characteristic fossil in this formation, and that it has also been found at Windrush Quarries, the neighbourhood of Miserden Park, and Notgrove*, all of which localities are in the Gloucestershire district.

The national collection at South Kensington contains a few individuals from the Stonesfield Slate of Northleach in the same district; they are most probably the earliest known species of the genus. It perhaps extends upwards into the Forest Marble, though, with the possible exception of the original of fig. 9, I have been unable to obtain any very satisfactory evidence of its occurrence in that bed. The specimen represented in fig. 9 is the property of J. F. Walker, Esq., M.A., F.G.S., who has kindly lent it to me for description. He obtained it from a workman, and there is therefore some doubt as to its exact horizon. Arm-fragments of the Lansdown Encrinite are said to occur in the Forest Marble; but I have not been able to verify this statement, and am therefore uncertain whether they may not belong to the common *Pentacrinus* of that bed.

I learn from Mons. P. de Loriol that this type is also found in the Jurassic beds of Calvados in Normandy; but I have no information as to its occurrence in other parts of the Continent.

II. Two new Comatulæ.

The examination of the palæontological collection in the British Museum, consequent upon its removal from Bloomsbury to South Kensington and its rearrangement in its new home, has led to the discovery of many forgotten rarities, including two fine *Comatulæ* from the Great Oolite and the Kelloway Rock respectively. I am indebted to the kindness of my friend Mr. R. Etheridge, jun., for the opportunity of describing them.

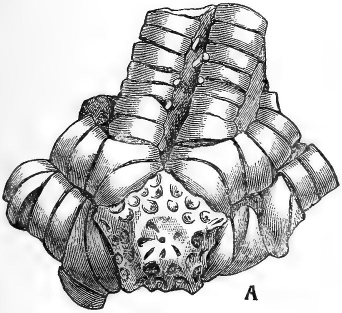
1. Antedon latiradia, n. sp. Fig. 1.

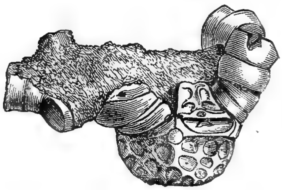
The centrodorsal is nearly hemispherical, its dorsal pole being slightly hollowed and marked with a faint stellate impression. It bears about 40 cirrhus-sockets, which are rather irregularly arranged. The first radials are partly visible round the edge of the centrodorsal, which conceals two of them almost entirely; at the interradial angles of the calyx they are separated from it by the small basals; their distal edges are deeply incurved in the centre, but turn outwards again at the sides. The proximal edges of the second

* This name is given as Nutgrove in Morris's Catalogue.

radials have a corresponding curve, so that these joints are considerably longer in the middle than at the sides, by the greater part of which they are united to their fellows. The pentagonal axillaries are short and wide, barely half as long again as the second radials,

Fig. 1.—*Antedon latiradia*, n. sp.





A. From beneath. B. From the side. (Twice the natural size.)
From the Great Oolite of Bradford.

their proportions being length : width =11 : 20. The first brachials are united for about half the length of their inner sides, which are shorter than the outer ones, owing to the inclination of the proximal and distal edges to one another. This is more markedly the case with the second brachials. The third brachial is a syzygial or double joint, and the two following joints are transversely oblong. On one of the three remaining arm-bases the fifth brachial is also a syzygial joint.

The articular face of one first radial is visible. It is roughly trapezoidal in shape, 4 mm. high, and a trifle wider across the transverse ridge, which rises up around the opening of the axial canal into a triangular articular surface. Beneath this is a small fossa with a deep central pit for the insertion of the dorsal elastic ligament. The greater part of the articular face is taken up by the large plates for the attachment of muscles and ligaments, but the boundaries of their respective fossæ are not very distinct. There is a shallow but wide notch between the two muscle-plates, though it is not clear whether there was any vertical ridge descending from it towards the opening of the axial canal. If there was one, it became less marked as it approached the transverse ridge; for on each side of the apex of the triangular articular surface is a deepish pit which marks the central end of the ligament-fossa. These two pits are connected by a shallow depression above the apex of the triangle, so that the whole has somewhat of an hourglass-shape.

Size. Diameter of centrodorsal 7·5 mm.; diameter across the circle of radial axillaries 14 mm.

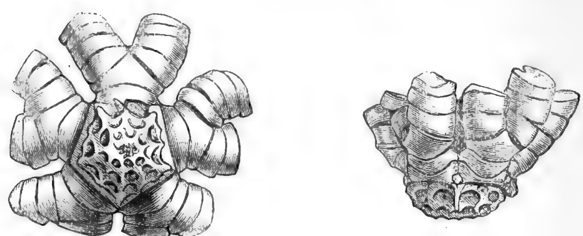
Locality and horizon. The Great Oolite, Bradford.

2. Antedon calloviensis, n. sp. Fig. 2.

Actinometra calloviensis, P. H. Carpenter, Abstracts of the Proceedings Geol. Soc. no. 407, June 22, 1881, p. 98.

The centrodorsal is low and basin-shaped, slightly produced at the interradial angles, and nearly covered by about 30 cirrhus-sockets. The lowest joint of one (probably mature) cirrhus is still attached to its socket, and close to it is the basal portion of another, but much younger one. The first radials are partially visible all round the edge of the centrodorsal, from which they are separated at the interradial angles of the calyx by the small basals; their line of junction with the second radials is rather incurved, though less so than in the preceding species. The second radials are very convex, and widely hexagonal, being only united to their fellows by less than half their length. The axillaries are wide and pentagonal, and less than twice the length of the second radials, their

Fig. 2.—*Antedon calloviensis*, n. sp.



A. From beneath. B. From the side. (Twice the natural size.)
From the Kelloway rock of Sutton Benger.

proportions being length: width $=10:17$. The first brachials are united in pairs for about half their length by their inner ends, and their terminal edges are nearly parallel; while the second are somewhat more wedge-shaped, their inner sides being considerably shorter than the outer ones. The oblong third brachial is usually a syzygial or double joint, one out of the five which remain being an exception to this rule. The first joints of the pinnules on the second brachials are visible at the bases of one or two arms.

Size. Diameter of centrodorsal 6 mm.; diameter across the circle of radial axillaries 11·5 mm.

Horizon and locality. The Kelloway Rock of Sutton Benger.

Remarks. These two species, occurring at different horizons, are very closely allied. *Ant. calloviensis* has fewer cirrhi and a less spreading centrodorsal, so that the first radials are visible all round, and not more or less completely concealed as is the case with some of those of *Ant. latiradia.* The second radials, too, have their proximal ends less closely united than in *Ant. latiradia.* The

axillaries of the two species also differ in their relative proportions; and the same is the case with the first brachials, those of *Ant. latiradia* being the more wedge-shaped. Both species, like most of the Jurassic *Antedons*, belong to a section of the genus which is less sharply distinguished from *Actinometra* than the great majority of recent species are. In most recent *Antedons*, especially in those which resemble these two species in having only ten arms, the axillaries are nearly as long as, or sometimes even longer than, wide, and have more or less marked backward projections into the second radials. This last feature is visible even in *Ant. macrocnema* of Sydney Harbour, which is remarkable for presenting many of the peculiarities of Jurassic *Antedons*. It likewise approaches *Actinometra* in the relative width of the axillaries, and also of the articular faces of the first radials. In most recent *Comatulæ*, including some species of *Antedon* and all *Actinometræ*, the width of the articular faces of the first radials exceeds their height, though in some *Antedons* these faces are higher than they are wide; but the relative proportions of the two diameters vary considerably, the width being greatest in the *Actinometræ*. The same is the case with the dimensions of the radial axillaries, as may be seen from the subjoined Table:—

Species.	Articular faces of first Radials. Proportion of width to height.	Radial Axillaries. Proportion of width to length.
RECENT.		
Antedon Eschrichtii	11 : 10	16 : 15
—— macrocnema	6 : 5	8 : 5
Actinometra strata	16 : 9	2 : 1
—— Jukesii	7 : 5	5 : 2
FOSSIL.		
Antedon latiradia	17 : 16	20 : 11
—— calloviensis	....	17 : 10

In this last respect the two fossil species under consideration approach the type of *Actinometra* rather than that of most *Antedons*, though the axillaries of *Ant. calloviensis* are but little wider than those of *Ant. macrocnema* and other somewhat aberrant species. The articular faces of the first radials are not exposed in *Ant. calloviensis*; and, in default of better evidence, I was at first led to refer this species to *Actinometra**, chiefly on account of its comparatively small centrodorsal and the width of its second and third radials. This took place before the discovery of *Ant. latiradia*, to which the Kelloway *Comatula* is evidently very closely allied. The older species has relatively wider axillaries than *Ant. cal-*

* Abstracts of the Proc. Geol. Soc. no. 407, p. 98.

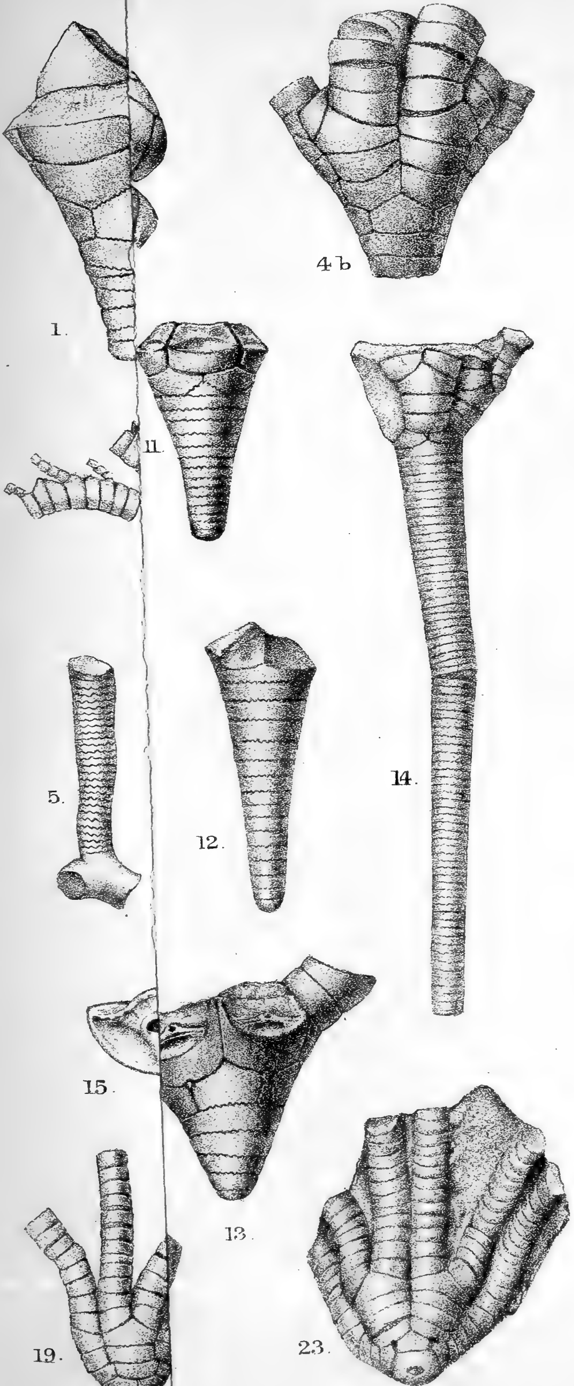
loviensis, though it has a larger centrodorsal, more numerous cirrhi, and higher articular faces on the first radials, so that it is clearly an *Antedon*. In their general *facies*, however, both species resemble the recent *Actinometræ* rather than the majority of recent *Antedons*. The same difficulty presents itself in the case of other Jurassic *Comatulæ*, which are very synthetic in their general characters, though some species can be classified without difficulty. Thus *Ant. Greppini*, *A. decameros*, *A. Tessoni*, and *A. scrobiculata* are unmistakable *Antedons*, with high radials and a large centrodorsal bearing numerous cirrhi; and *Actinometra wurtembergica* is a true *Actinometra*, with a flattened centrodorsal, free from cirrhi on its dorsal surface, and a wide calyx-funnel. But such forms as *Ant. Picteti*, de Loriol, and *Ant. infracretacea*, de Loriol, with their low wide radials and flattened centrodorsal imperfectly covered with cirrhi, approach very closely to the *Actinometra*-type; they retain, however, the sloping articular faces which are so characteristic of *Antedon*, and must therefore be referred to that genus.

Besides their tendency to combine the characters of recent generic types, the Jurassic *Comatulæ* are remarkable for their large size, as are also the Cretaceous species. The centrodorsal may reach from 9–13 mm. in diameter, which is greater than that of nearly every recent species except *Ant. Eschrichtii*; while this type and *Actinometra robusta* are almost the only living *Comatulæ* with arm-bases any thing like so massive as those of the fossil species. Taken as a whole, the group is chiefly confined to depths of less than 200 fathoms, and the larger specimens inhabit quite shallow water, 30 fathoms or less; so that *Ant. calloviensis* and *Ant. latiradia* must have lived not far from the shores of the Jurassic seas.

Postscript.

Since revising the proof of the preceding pages I have been favoured by Mons. Morière with a copy of his paper on "Deux Genres de Crinoïdes de la Grande Oolithe," which appeared in the 'Bulletin de la Société Linnéenne de Normandie,' sér. 3, vol. v. He describes the discovery of a *Millericrinus* in the upper part of the Great Oolite at Aunou-le-Faucon, a village 4 kilomètres from Caen; and he gives a photographic representation of a remarkable slab containing five specimens of *Apiocrinus Parkinsoni* and three of the *Millericrinus*. These last he identifies with *M. obconicus*, d'Orbigny, or, more correctly, *M. Prattii*. The arms of one specimen are preserved to a length of about 60 millim., and the length of its stem is still greater; but there is no trace of a root, its lowest portion having been broken away.

According to M. Morière, "Il ne reste plus à trouver aujourd'hui que la racine de ce Crinoïde." I am inclined to doubt, however, whether there is really any root for us to discover.



C. Berjeau. del

Mintern Bros. imp.

C. Berjeau del.

MILLERICRINUS PRATTII.

Mintern Bros. imp.

EXPLANATION OF PLATE I.

MILLERICRINUS PRATTII, Gray, sp.

(All the specimens represented, except that shown in fig. 9, are in the Woodwardian Museum. The original of fig. 9 is in the Cabinet of J. F. Walker, Esq., M.A., F.G.S.)

Fig. 1. Calyx and short stem with intercalated joint, side view: $\times$ 3.
2. Calyx, with a stem of only two joints, seen from beneath: $\times$ 2.
3. Calyx and upper stem-joints, with accessory basal pieces, side view: $\times$ 3.
4. Calyx with stem of four joints. *a*, from beneath; *b*, side view: $\times$ 2.
5. Portion of stem with indication of a root?: $\times$ 2.
6. Calyx with stem of about 60 joints: $\times$ 2.
7. Calyx with moderately long stem containing intercalated joints: $\times$ 2.
8. Calyx with stem of about 50 joints: $\times$ 2.
9. Remains of a tolerably complete specimen with a stem of 2 joints: $\times 1\frac{1}{2}$.
10. Calyx with stem of about 20 joints: $\times$ 3.
11. Calyx with stem of 15 joints: $\times$ 2.
12. Remains of a stem of 16 joints: $\times$ 2.
13. Calyx with 5-jointed stem: $\times$ 3.
14. Calyx with stem of 70 joints: $\times 1\frac{1}{2}$.
15. Distal articular face of a second radial: $\times$ 4.
16. Inferior aspect of basal pentagon: $\times$ 3.
17. Calyx and upper stem-joints: $\times$ 3.
18. Imperforate and rounded top stem-joint with basals attached; from beneath: $\times$ 4.
19. Calyx with arms attached: $\times$ 2.
20. Calyx with upper stem-joints. *a*, from above; *b*, from the side: $\times$ 4.
21. Calyx with upper stem-joints which are enclosed in an additional limestone deposit: $\times$3.
22. Inferior aspect of the top stem-joint of a stalked individual, with facet and axial canal and the basals attached: $\times$4.
23. Calyx with 2-jointed stem and arms attached: natural size.

4. Notes *on the* Polyzoa *of the* Wenlock Shales, Wenlock Limestone, *and* Shales *over* Wenlock Limestone. *From material supplied by* G. Maw, Esq., F.L.S., F.G.S. By George Robert Vine, Esq. (Communicated by Dr. H. C. Sorby, F.R.S., F.G.S.) (Read December 7, 1881.)

Introduction.

The organisms found in the Wenlock Shales of Shropshire have been already alluded to by Mr. Maw and by Mr. Davidson in their joint paper in the 'Geological Magazine' for the year 1881 *. The remarks of these authors bore chiefly upon the Brachiopoda found in the shales; but the other organisms were casually alluded to in passing. Since this joint paper was written, I have had an opportunity of working over nearly one hundredweight and a half of the débris, and this, in all probability, may represent from six to eight tons of the unwashed clay. My object in searching was principally to pick out the Polyzoa and the smaller Actinozoa of the débris; but in doing this I felt very reluctant to pass over organisms which belonged to other than these two classes; consequently, to some extent, my collection consists of specimens illustrative of the Actinozoa, Echinodermata, Annelida, Crustacea, and Brachiopoda, as well as the Polyzoa of the shales. It is not my intention in the present paper to commit myself to remarks on the genera belonging to these classes otherwise than by presenting a Table of the whole series of associated fossils. This Table is divided into twelve columns, eleven of which are allotted to the several localities from which Mr. Maw supplied me with material; the other column affords me the opportunity of completing the range of species by recording their presence in the Wenlock Limestone. I have no desire to speak of species found in the cabinets or collections of others. Every organism against which a mark is placed, with the exception of those from the Wenlock Limestone, has been found in the shales supplied by Mr. Maw; and even the Brachiopoda are given, not from the lists of Messrs. Maw and Davidson, but from my own pickings from the shale. To do this properly, Mr. Davidson has kindly named for me a set of specimens submitted to him for that purpose, and to these I have since been able to add a few others.

It is to be regretted that much of the finer material has been lost in the washing: but in every case, before I parted with the picked material, I sifted the refuse through coarse net and also fine muslin; and, after rewashing, I was thus enabled to pick out and mount a very fine series of Entomostraca. My types of these have been kindly examined by Prof. Rupert Jones, and upon his authority I am able to say that several of the specimens are either new species or new varieties. These Entomostraca are in a fine state of preservation as regards the carapace, and they will enable me, in working

* January, March, and April.

out the details, to add many particulars to our present knowledge respecting their range and variability in the shales. It will suffice for the present if I merely remark that the *Primitiæ* and some of the *Beyrichiæ* have a closer affinity to Swedish than to British types. The close resemblance of some of the *Cytheræ* and *Cytherellæ* to Carboniferous forms has already been alluded to by Prof. Rupert Jones, F.R.S.

I have not been able to add many species to the class Annelida. I have not had such free access to the literature of the class as I could have desired; but several of the washings have yielded a large variety of Annelids, whilst in other washings I have not found a single one. *Spirorbis* is remarkably rare.

The Echinodermata are mainly represented by the jointed stems of several species of Crinoidea, and the cups of two species at least, one of which is apparently related to *Cyathocrinus ramosus*, Schl., as figured by King in his 'Permian Fossils,' pl. vi. figs. 1 and 2. An immense number of separated costal plates and many scapular plates of Crinoids, and some few plates of Cystoids, similar to those alluded to and figured by Nicholson and Etheridge in the 'Monograph of Silurian Fossils' *, fasc. iii. pl. 22, are also present.

The Crustacea, excepting the Entomostraca, are represented by fragments of Trilobita, several of the separated elements of the head, thorax, and pygidium, some of which are well preserved.

The Actinozoa are also largely represented both as species and individuals. Some of the genera are *Monticulipora* and its several subgenera, *Alveolites*, *Cœnites*, *Halysites*, and *Heliolites*; but these require separate working, since the writings of Professor Nicholson have shown how fallible are all the descriptive labours founded upon external facies or of habit only. The genus *Fistulipora*, M'Coy, the separated fragments of *Syringopora fascicularis*, Ed. & Haime, and *Alveolites*? *seriatoporides* are very abundant.

In only one washing, that of the shales over the Wenlock Limestone, have I found any fragments of Plantæ; and these I can only refer to doubtfully. The Macrospores in the list are, however, unique; they are unlike the Macrospores of the Carboniferous series; but even these I cannot build much upon. Nevertheless they find a place in the Catalogue.

With regard to the Polyzoa of the shales the paper itself will be sufficiently explicit. I am surprised that so few genera are represented, and, comparatively speaking, so few species. Some of the species are very scarce, so that I have had, to a large extent, to depend upon external characters. Apparently many more species could have been added to the list; but I have preferred to restrict the number unless there was ample evidence to support their being placed with the class. There has been a tendency of late amongst palæontologists to pass over from the Actinozoa to the Polyzoa some at least of the species that have heretofore been placed with the Tabulata; and Milne-Edwards and Haime, in their 'Silurian Corals' †, had their

* 'Monograph of the Silurian Fossils of the Girvan District in Ayrshire.'

† Pages 276–278.

doubts as to whether *Cœnites* belonged to the Corals or the Bryozoa. In every instance where a doubt was expressed by an author as to the proper class to which species should be referred, I have made original investigation for the purpose of satisfying myself; and, so far as these experiments and investigations will justify me in forming an opinion, I may say unhesitatingly that neither the species of *Monticulipora*, to which reference has been made by authors, nor *Cœnites* can be referred to the Polyzoa.

In all my investigations of Silurian Polyzoa I have been haunted by the keen remarks of Prof. Owen * :—"The practical palæontologist finds himself compelled to arrange and study the fossil Bryozoa along with the corals, if only on account of the difficulty he in many cases experiences of determining to which class of Polypi his specimens belong . . . . . . The real merits of the man who would make scientific capital by changing the position of such a group, and by imputing error or ignorance to the author from whom he may differ in this respect, are easily weighed and soon understood."

I have ventured to differ from Prof. Owen as to the position, in a natural classification, the Polyzoa should occupy; but I hope I have not merited the severe judgment implied in the last sentence. Still it will be very unsafe to allow the present classification of types, such as Chilostomata and Cyclostomata, to prejudice the mind of the systematist. So far as my experience goes, such arbitrary divisions, when we get below the Cretaceous groups of Polyzoa, barely represent the truth; and in the Palæozoic division it is impossible to bring out the whole of the truth when we attempt to carry modern divisions beyond a certain stage. In my Report on the Silurian Polyzoa † I have endeavoured to limit the disposition to give a modern expression to ancient groups. Still I felt that if I carried this objection into practice I should only displace one arbitrary method by substituting another. I have therefore in that Report allowed the full expression of the truth to come to the front suggestively, by the temporary arrangement which I have given. There is a pressing necessity for an intermediate division to take in forms which can neither be placed as Chilostomata nor as Cyclostomata. Before this can be done with any degree of satisfaction some primary basis of classification must be agreed upon by palæontologists, and this not hurriedly or vaguely. For myself, I would suggest that the classification of Palæozoic Polyzoa be based on the arrangement and character of the cells as shown in typical sections, and not wholly on the habit of species. There is in every species of Palæozoic Polyzoa with which I am familiar both a peculiar cell-arrangement and a peculiar habit; and if these expressions were formulated the Palæozoic types could be very readily arranged in groups which would be allied to similar groups found in the Oolitic and Cretaceous series. No outrage upon existing groups would then be needed, but a real foundation for a natural classification would thus be effected. It is very certain that peculiar types of

* 'Palæontology,' ed. 1860, p. 27.

† Brit. Assoc. Report, ii., "Silurian Polyzoa," York, 1881.

Palæozoic Polyzoa came into existence in the remote ages of the past, and died out in later, still remote ages; but having no natural or generally accepted standard to judge by and compare with, we are at a loss to give full expression to any truth which certain species may present. Amongst the Tertiary and recent Polyzoa this difficulty is not so much felt; and I for one shall be inclined to accept Mr. Hincks's fuller classification when the results of his investigations amongst other than British Polyzoa have satisfied him that he is right. For the present I am chiefly concerned about the Palæozoic and Mesozoic types.

When the material was sent to me by Mr. Maw, every box or parcel had a particular number. This I have preserved; and the different numbers at the tops of the columns are the numbers supplied to me. They are as follows:—

Lower Wenlock Shales .. "Buildwas Beds †".. 22, 36, 37, 38, 40.
Middle Wenlock Shales .. "Coalbrookdale Beds" 43.
Upper Wenlock Shales .. Tickwood Beds...... 25, 41, 42.
Wenlock Limestone. No material supplied.
Shales *over* the Wenlock Limestone .... 24, 46.

In the following list I have only indicated by an asterisk the presence of certain species of Actinozoa. I have not in every instance given the species, for reasons already stated. I have, however, given as full a record as possible. Referring to the Entomostraca, because certain species are left bare of a mark, it must not be supposed that species cannot be found in the shales; it only means that mine are bare of forms in that particular locality, because I have not had material fine enough for examination.

Vertical Range of Genera and Species found in the Wenlock Shales of Shropshire (Mr. Maw's washings).

Genera and Species.	46.	24.	W. L.	25.	41.	42.	43.	40.	38.	37.	36.	22.
PLANTÆ.												
Macrospores	v r											
ACTINOZOA.												
Heliolites interstinctus, *Wahl.*...	...	...	...	*	*	*	*					
—— sp.	...	...	...	*	*							
Favosites (wants working)	*	...	...	...	...	...	...	...	...	*	*	
Halysites catenularius, *Linn.* ...	...	...	...	*	...	*	*					
Syringopora, sp.	*	...	...	*	*	*	...	...	...	...	...	*
Alveolites, sp. (wants working)...	*	*	*	*	*	*	*	*	*	*	*	*
—— seriatoporides, *M.-Edw.* ...	...	...	...	*	*	*	*	...	...	...	*	
Cœnites juniperinus, *Eichw.* ...	...	...	...	*	...	*	*	...	*			
—— intertextus, *Eichw.*	...	...	...	...	...	...	*	...	*			
Monticulipora, sp. (very rich; but the whole wants working.)	*	*	*	*	*	*	*	*	*	*	*	*
Fistulipora, sp., *M'Coy*	...	...	...	c	...	c	c	*	*	*	*	r

† In my former paper "On Silurian Uniserial Stomatoporidæ" I spelt this name incorrectly "Buildwass."

Vertical Range of Genera and Species (continued).

Genera and Species.	46.	24.	W. L.	25.	41.	42.	43.	40.	38.	37.	36.	22.
ECHINODERMATA, sp.												
Plates, stems	*	*	*	*	*	*	*	*	*	*	*	*
Calices	...	...	...	...	...	...	...	...	...	*	*	
Stems bored by Sponge?	...	...	...	...	...	...	*	...	...	*	*	*
ANNELIDA.												
Cornulites serpularius, *Schloth.*	...	...	...	...	*	...	...	...	...	...	...	*
Tentaculites annularis, *Schloth.*	...	...	...	*	...	...	...	*	*			
—— tenuis	*	...	...	...	...	...	...	...	...	...	...	*
Ortonia, sp., *Nicholson*	...	...	...	...	...	...	...	*	*			
Spirorbis	*											
TRILOBITA.												
Fragments of Trilobites are found in nearly all the washings; but these require very careful working	*	*	...	*	*	*	r	*	*	*	*	*
ENTOMOSTRACA †.												
Bairdia elongata, *Münst.* (?)	r	...	...	...	...	...	r(?)	...	r			
—— ?, sp.	r	...	...	...	...	...	...	...	r			
Thlipsura, sp. n. (*Jones*)	c	...	...	c	...	...	...	...	c r			
—— corpulenta, *J. & H.*	c											
—— ——, var. scripta	r	...	...	c r								
—— tuberosa, *J. & H.*	...	...	...	r								
Cythere bilobata, *Münster* (near)	r	...	...	r	...	...	r					
—— intermedia, *Münster* (near)	...	...	...	c	...	...	...	...	...	...	...	?
—— sp.	r	...	...	r	...	...	r	...	...	...	...	r
Cytherella, sp. n. (*Jones*)	r	...	...	...	...	...	...	...	...	...	...	r
Primitia renulina, *Jones* (near)	r	...	...	...	...	...	r	...	c r	c r		
—— ovata, *J. & H.*	r	...	...	r								
—— variolata, *J. & H.*	c r	...	...	...	...	...	...	...	c r	c r		
—— cristata, *J. & H.*	...	...	...	r								
Beyrichia Klodeni, *M'Coy*	c r	...	...	...	...	...	r	...	...	c r	...	c r
——, var. tuberculata, *Salter*	c	c	...	c	...	...	...	...	...	...	...	c
——, var. torosa, *Jones*‡	...	r	...	r	...	...	...	...	r	r		
Kirkbya (?), sp.	...	...	...	r								
POLYZOA.												
Ptilodictya lanceolata, *Goldfuss?*	...	...	c									
—— Lonsdalei, *Vine*	v r	...	...	v r	c	...	...	c	c	...	c c	c c
—— scalpellum, *Lonsdale*	...	...	...	c	r	v r	...	c r	c r			
—— interporosa, *Vine*	...	...	...	...	...	v r						
——, sp. n. (?)	...	...	...	v r								
Phyllopora, sp.	...	...	r									
Berenicea, sp. (wants working)	...	...	c	r	...	...	...	...	...	...	r	
Fenestella prisca, *Lonsd.*	...	...	...	r								
—— reteporata, *Shrubsole*	...	...	*									
—— lineata, *Shrubsole*	...	...	*									
—— intermedia, *Shrubsole*	...	...	*									
Glauconome disticha, *Goldfuss & Lonsdale*	v r	...	c c	c								

† See Geol. Mag., Mr. Smith's List, February 1881; also August same year.
‡ There are still several species of *Beyrichia* which require reworking.

Vertical Range of Genera and Species (continued).

Genera and Species.	46.	24.	W. L.	25.	41.	42.	43.	40.	38.	37.	36.	22.
Hornera ? crassa, *Lonsdale*	...	...	r	c								
—— ? delicatula, *Vine*	...	...	...	...	...	...	...	...	...	...	...	c r
Stomatopora dissimilis, *Vine* †	...	...	...	v r	...	v r	...	r	c	...	c	
—— ——, var. elongata, *Vine*	...	...	...	...	...	...	...	...	r	...	c	r
—— ——, var. compressa, *Vine*	v r	...	c									
Ascodictyon stellatum, *Nich.*	...	...	...	...	...	...	...	...	...	...	c r	
—— ——, var. siluriense, *Vine*	...	...	...	...	...	...	...	...	c r	r	c r	
—— radiciforme, *Vine*	...	...	...	...	...	...	...	...	c r	...	c	
—— filiforme, *Vine*	...	...	...	r	...	...	v r	...	c	...	c	c
Diastopora consimilis, *Lonsd.*	...	...	r ‡	...	...	...	...	v r				
Ceriopora oculata, *Goldfuss*	r	...	...	...	...	r	...	...	...	...	c	
—— granulosa, *Goldfuss*	r	...	...	...	...	c	...	...	...	...	c	
Spiropora regularis, *Vine*	r	r	r	v r	...	...	...	r	c r	r	c	c
—— intermedia, *Vine*	...	...	...	r								
Discopora, sp., *Lonsd.*	c	...	...	c								
Ceramopora, sp.	r	...	r	...	...	r						
BRACHIOPODA §.												
Lingula Symondsii, *Salter*	...	...	...	...	...	...	...	*	*			
Orbiculoidea Forbesi, *Davidson*	...	...	...	...	...	...	...	...	*	...	*	
Pholidops implicata, *Sow.*	...	...	...	*	...	...	...	...	r	...	...	r
Waldheimia Mawei, *Dav.*	*	...	...	*	...	...	...	...	*			
Meristella læviuscula, *Sow.*	...	...	...	*	...	...	...	...	*	...	...	r
Spirifera plicatella, *Linn.*	...	...	...	...	...	...	*					
—— ——, var. radiata, *Sow.*	...	...	...	*								
—— crispa, *Linn.*	...	...	...	...	*	*	...	...	*			
Nucleospira pisum, *Sow.*	...	...	...	...	*							
Atrypa reticularis, *Linn.*	...	...	...	*	*	*	...	...	*	*		
—— Barrandi, *Dav.*	...	...	...	...	...	...	...	...	*	...	*	
Glassia obovata, *Sow.*	...	...	...	...	...	...	...	...	*	*	*	
Retzia Bouchardi, *Dav.*	...	...	...	*	*	...	...	...	...	...	*	
Eichwaldia Capewelli, *Dav.*	...	...	...	...	...	...	...	...	*	...	*	*
Streptis Grayi, *Dav.*	...	...	...	...	...	...	...	...	...	...	...	r
Pentamerus, sp. ‖	...	...	...	...	...	...	...	...	*	*	*	
Rhynchonella, sp. ‖	...	...	...	...	...	...	...	*	*	...	*	*
—— bidentata, *Sow.*	...	...	...	...	...	...	...	...	...	*		
Orthis biloba, *Linn.*	*	...	*	*	*	...	...	*	*	*	*	*
—— Lewisii, *Dav.*	...	...	...	*	*	*	...	*	*	*	*	*
—— hybrida, *Sow.*	...	...	...	*	*	*	*	*	*	*	*	*
—— rustica, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	*
—— elegantula, *Dalm.*	...	...	...	*	*	*	*	*	*	*	*	
—— elegantulina, *Dav.*	...	...	...	...	...	...	...	...	...	*	*	
Strophomena rhomboidalis, *Wilkens*	...	...	...	...	...	...	...	*				
Leptæna segmentum, *Ang.*	...	...	...	...	...	...	...	*	*	*	*	*
Chonetes minima, *Sow.*	...	...	...	...	...	...	...	...	...	...	...	*
—— lepisma, *Sow.*	c											
GASTEROPODA, sp.	...	...	...	*	...	*	...	*	*	*	*	*

† Another species, which I have simply indicated by the name of *Polypora problematica*, is rather abundant. It was left unnamed by Salter, and was a puzzle to him; it is also a puzzle to me.

‡ School of Mines.

§ See Geol. Mag., March 1881, pp. 108, 109.

‖ I cannot work these out satisfactorily.

The Polyzoa of the Wenlock Shales, the Wenlock Limestone, and Shales over Wenlock Limestone.

Class POLYZOA, J. V. Thompson.

Order GYMNOLÆMATA, Allman.

Suborder CYCLOSTOMATA, Busk.

Group II. INCRUSTATA, d'Orbigny.

Inarticulatæ s. *Adfixæ*, Busk, Crag Polyzoa.
Inarticulata, Busk, Brit. Mus. Cat. pt. iii.
"*Zoarium* calcareous, continuous, not divided by corneous joints, or furnished with radical tubes; erect and attached by a contracted base, or recumbent and immediately adnate, either wholly or in part" (Hincks, Brit. Mar. Polyzoa, p. 424).

Genus STOMATOPORA, Bronn.

1821. *Alecto*, Lamx. (1814, introduced by Leach for a genus of Echinoderms).
1825. *Stomatopora*, Bronn; d'Orbigny (for uniserial species).
Zoarium creeping, adnate, irregularly branched. *Zoœcia* in single series.

1. STOMATOPORA DISSIMILIS, Vine.

Stomatopora dissimilis, Vine, Quart. Journ. Geol. Soc. vol. xxxvii. p. 615.

This species has already been fully described and illustrated in a paper read before the Geological Society, and published as above.

Locality. Buildwas Beds, near base of Wenlock Shale. Washings nos. 22, 36, 38. Mr. Davidson's list, no. 10.

2. STOMATOPORA DISSIMILIS, Vine, var. *a*, ELONGATA.

Zoarium very irregular, clustering. *Zoœcia* elongated, with, at times, long stoloniferous processes which intermingle with the cells. When colonial growth is distinct, arrangement of cells linear and uniserial. Measured under favourable circumstances, about three cells occupy the space of one line.

The variety of this species which I distinguish by the name *elongata*, is present in the various washings in which the *S. dissimilis* is found. Its distinguishing peculiarities are its elongated cells and its clustering habit.

Locality. Buildwas Beds. Washings nos. 22, 36, 40.

The uniserial *Stomatoporæ* of the Wenlock Limestone have been noticed or alluded to by Lonsdale, Salter, M'Coy, and other workers on the fossils of the Palæozoic era; but neither in the 'Silurian System' nor in 'Siluria' is there any detailed account of the species.

After my descriptions were written, I was surprised to find in the cabinets of my friends such a mass of really good undescribed material. Recently Mr. F. D. Longe, F.G.S., has drawn attention to some of the features of the Wenlock-Limestone *Stomatoporæ*. His paper not being published, I cannot say whether he distinguishes the form by a name. If not, to complete this description, I give it a varietal one.

3. Stomatopora dissimilis, Vine, var. *b*, compressa.

The zoœcia of this variety are stunted and closely compacted together, forming lines as in fig. 1, p. 616, Q. J. G. S. Nov. 1881, also dense masses covering, by their prolific habit of growth, large spaces on shells, Brachiopods, and corals. But that the Rev. A. M. Norman has already used the name *compacta* for a species of *Stomatopora* from Shetland, this would have been a far preferable name for the variety. It is hard to make out the true characters of *Stomatopora* in some of these clusters; and in many of the more vigorous colonies the whole of the calcareous coatings or true cells are destroyed, leaving nothing behind but the dark-brown matrices, without the least distinguishing feature, an accident which to some extent renders identification difficult. Measured under favourable circumstances (that is, where the cells are linear), about three zoœcia occupy one line. In this respect it has a measurement nearly the same as variety *a*; but taking into consideration the elongated character of the cell of this species, the variety *compressa* has the advantage in size. The generally compressed habit of colonial growth is also a special feature. At first sight there is a striking similarity to the form figured and described in King's 'Monograph of Permian Fossils' * as *Aulopora Voigtiana*, King.

Locality. This variety I have never detected *below* the Wenlock Limestone; and in the shales over the Limestone (no. 46 of the washings) I have only found one poor specimen on a crinoid stem.

Seeing that I have differed from Prof. H. A. Nicholson † as to the classificatory position his species, described as *Hippothoa inflata* (*Alecto inflata*, Hall), should occupy, I have studied the so-called *H. inflata* again, upon specimens sent me by Prof. Nicholson himself. I cannot, however, see any thing in the species to make me qualify my expressed opinion. In some of the colonies we have specimens similar to var. *elongata*, Vine; others are more stunted and inflated; whilst some few colonies have their individual cells so inflated as to force the orifice into a subterminal position, and the stolon-like elongations give this appearance a Hippothoid character; but beyond this there is no Chilostomatous affinity. I have not (after the closest search) found the least trace of an ovicell or a sinuated orifice in the American Lower Silurian *Stomatoporæ*.

* Page 31, pl. iii. fig. 13.

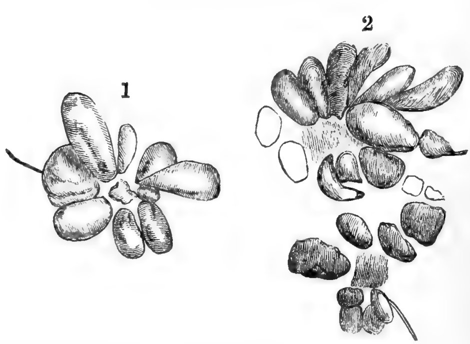
† Brit. Assoc. Report, 1881, York.

Ascodictyon, Nicholson and Etheridge, jun., Ann. & Mag. Nat. Hist. June 1877.

Gen. Char. "Organism composite, parasitic, adherent on foreign bodies, composed of numerous calcareous cells or vesicles, the walls of which are perforated by a greater or less number of microscopic foramina, but which possess no single large aperture. The cells may be united almost directly by the intervention of short tubular necks: or they may be disposed in clusters connected with one another by hollow filamentous tubes, which usually anastomose, and which, in some cases, at any rate, are likewise perforated by microscopic pores"*.

This genus was established by the authors for species found in the Devonian formation of America and the Carboniferous of Scotland. I have not seen the Devonian species, and I rely on the general accuracy of Prof. Nicholson's details with regard to these. With our own Carboniferous species I am very familiar. Since having the plentitude of washed shales supplied by Mr. Maw, I have been able to examine some hundreds of specimens on stems of crinoids, broken shells, and corals. This circumstance has helped me to understand and work out many biological details the narration of which would be out of place in a general paper like the present. I accept the genus of Prof. Nicholson and Mr. Etheridge; and, so far as I am able at present, I give below descriptions of the various species found within a very limited range in these shale-washings.

Figs. 1 & 2.—Ascodictyon stellatum, *Nich. & Ether., var.* siluriense, *Vine.*



Several rosettes, showing the habit of the colonies, together with a few of the filaments: × 24.

4. Ascodictyon stellatum, var. siluriense. (Figs. 1 & 2.)

Messrs. Nicholson and Etheridge characterize their *Ascodictyon stellatum* as follows:—

* Nicholson and Etheridge, work cited above, p. 463.

"Colony composed of ovoid or pyriform calcareous vesicles, varying in length from one fifth to one third of a line, and usually disposed in stellate clusters, each containing from three to six cells, or sometimes more"*. In the Devonian species the cells are distinctly foraminated in lines, a feature that I have not detected in the Silurian specimens. In other respects, in the arrangement of the stellate clusters, the partially isolated vesicles, and the connexion of these by stolon-like processes, the species and the variety are very similar. The vesicles in the Silurian variety vary from about one sixth to one fifth of a line in length.

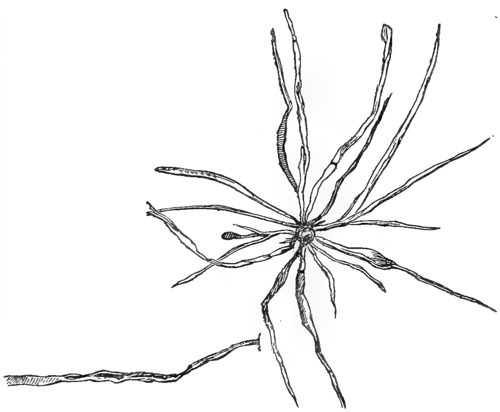
Obs. Accepting freely the full description of the species as given by Messrs. Nicholson and Etheridge, jun., I have thought that it would be best to give only those characters that are found in my Silurian specimens. I thus avoid making a new species; but by distinguishing it by a varietal name prominence is given to an earlier type.

Habitat. On stems of crinoids and broken shells.

Localities. Buildwas beds. Rather frequent in those marked 36 and 38, somewhat rare in the other washings.

Fig. 3.—Ascodictyon radiciforme, *Vine.*

3



The general habit of the clustering filaments round a central axis: ×24. The specimen selected for illustration is typical of the whole group; but there are many varieties of stellate clusters.

5. Ascodictyon radiciforme, sp. n. (Fig. 3.)

Sp. Char. Colony composed of elongated root-like processes, which vary in length from three quarters of a line to a line. These processes are sometimes jointed; and they are disposed in circles, unevenly developed, radiating round a common axis, which may be

* Nich. *op. cit.* p. 464.

only a mere point or a "central circular depression"*. Vesicles fusiform, or tongue-like; their bases connected with the central axis by hollow filamentous cords. The vesicles are rarely simple, as shown in *A. radians*, Nich. and Eth., but are in most cases jointed; and these bifurcate at intervals, and ultimately pass outwards into fine cord-like filaments, which may or may not connect other stellate groups. In the free surfaces of some of the vesicles "the excessively minute, closely approximated pores" referred to by Nicholson in his description of his type, may be detected, although sometimes with difficulty, in the Silurian species also. Some specimens measured across the centre either way are from one and a half to two lines; and the number of vesicles to each rosette varies from four to twelve.

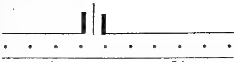
Obs. At first I was inclined to regard this species as a variety of *A. radians*, Nich. and Eth. In working out the details, I found that I was obliged to adopt a new specific name. *A. radians* of the above authors is a typical Scottish Carboniferous fossil; and although some of the specimens from different localities vary in facial outline, still the differences between the Carboniferous and the Silurian species are too decided in character to be lightly passed over. The rosettes of the Carboniferous forms are very regularly formed round a central axis; the rosettes of the Silurian species are very irregularly placed; and the earlier form is also much larger than the species described by Nicholson.

Localities. Buildwas beds, 36 and 38 of the collection generally, rarely in the other washings from these beds. Above the Buildwas beds I have found but few minute fragments; in all probability these are stray specimens from either 36–38 or 40. I have not been able to detect in these washings the least fragment of *Ascodictyon fusiforme*, Nich. and Eth. The anomalous character of this type leads me to suspect that the species, whatever it may be, is not an *Ascodictyon*, the true types of which may be accepted, extreme though they be in individual character, as *A. stellatum*, Nich. and Eth., *A. radians*, Nich. and Eth., and the new type described above, *A. radiciforme*, Vine. We have these typical species from the Silurian Wenlock Shales, Shropshire, the Middle Devonian of Ontario, and the Carboniferous Limestone series of Scotland.

6. Ascodictyon filiforme.

I cannot help putting upon record this name; but I have no desire to establish it as a species. On several fragments of shell, on stems of Encrinite, and in some rare instances on other organisms, I find filamentous threads bisecting other threads, the points of bisection in some cases swelling out. There is in this a biological peculiarity to which it may be well to direct attention; and I cannot do this better than by giving a name to this peculiarity, so as to individualize the type. Otherwise these filamentous cords belong to the species of *Ascodictyon* described. They are hollow; but a

* Nich. and Eth. Ann. & Mag. Nat. Hist. 1877, vol. xix. p. 465.

dark line  occupies the place of the life-pulp which passed through the living filament. The first indication of a vesicle is a bulbous projection of this vital cord, 

For reasons already given *, I have allowed my descriptions of *Ascodictyon* to follow the descriptions of *Stomatopora*. Since my former paper was written I have examined some hundreds of specimens of crinoid stems and broken shells, more or less incrusted with *Ascodictyon* and *Stomatopora*, and I have not seen any thing that would suggest a different opinion from the one already expressed.

Spiropora, Lamx.

1821. *Entalophora*, Lamx.
1821. *Spiropora*, Lamx.
1834. *Pustulipora* (pars), Blainville.

The desire on the part of Mr. Hincks † and Prof. Brauns ‡ to return to original descriptions rather than adopt some one or other of the synonyms which are of later date is to be commended. It may be justifiable to adopt for recent species the genus *Entalophora*; but in dealing with fossil types, there are many species that could not be conveniently placed under that name. The genus *Spiropora* has been very appropriately used by both Jules Haime and Prof. Reuss in their works on the Jurassic and Eocene Bryozoa. Both these authors limit the genus to species which show a peculiar spiral arrangement of cells, independent of the fact that all three of the genera whose names are placed above have tubular cells which open on all sides. In like manner I limit the genus for a very unique palæozoic type of Polyzoa which had a very wide range in Silurian times.

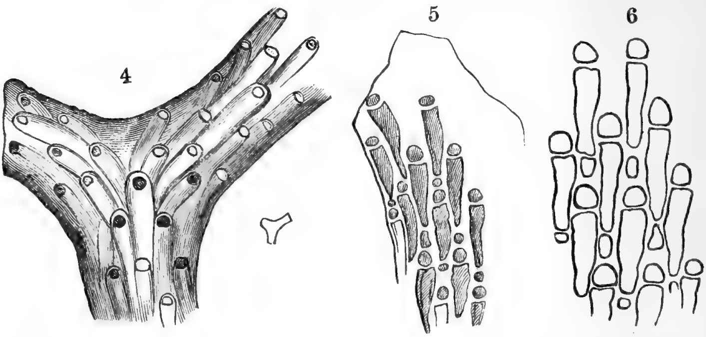
7. Spiropora regularis, sp. n. (Figs. 4, 5, 6.)

Zoarium erect, dichotomous, branches rarely exceeding half a line in breadth. In its earliest stages the zoarium is attached by a disk-like base to some foreign object. *Zoœcia* very regularly disposed, spirally, round the whole stem and branches, on the main stem in alternate rows. The normal condition is for the zoœcia to be slightly conical and covered with a delicate chalky crust; this, however, is rarely preserved. When worn, the walls of the cells are exposed; and in this condition the spirals are better shown. It is then seen that every alternate cell, for half its length, is so far separated from its neighbour as to allow the half of the alternate cell above to pass down and occupy the space thus left vacant; at the base of each cell a small secondary opening is thus exposed. Aperture round; peristome slightly raised in some cases. Two cells occupy the space of a line in a longitudinal direction; from five to eight cells are found on the whole circumference of the stem; and they vary in number on the branches.

* "Silurian Uniserial Stomatoporæ," Quart. Journ. Geol. Soc. Nov. 1881.
† Brit. Mar. Polyzoa.
‡ 'Die Bryozoen des mittleren Jura &c. von Metz,' D. Brauns, 1879.

It is only after very careful study that I introduce to the palæontologist, as a palæozoic type, this remarkable genus. Haime, in his 'Jurassic Bryozoa,' vindicates his use of the word *Spiropora* in place of the many synonyms which have been introduced into scientific literature since the time of Lamouroux. There are two very distinct

Figs. 4, 5, & 6.—Spiropora regularis, *Vine.*



4. Shows the general habit and mode of branching, and character of unworn cells: × 12. 5. Cells worn, showing the internal cast of the tubular cell: × 24. 6. Outline cells of a worn specimen, showing arrangement in spirals: × 24.

features in the genus; and these, as defined by Jules Haime, may be briefly noted:—1. The *Zoarium* is dendroid, with forked branches; cells elongated and closely connected. This feature is apparent in the Palæozoic type. 2. "The peristomes are circular and more or less projecting, and they form at the surface of the branches circles which usually are not closed, but each constitutes one of the turns of a spire so many times interrupted. These rings are the more regular the more distant they from each other. When they are very close they are often difficult to recognize"*. This feature is also present in the Palæozoic type. Haime, however, speaks of his species as being perforated "with very small and round pores." This feature is not present in this early type; indeed perforated pores are very rare in Palæozoic Polyzoa. I have seen them in some Carboniferous species of *Fenestella* †; but even in these they are of rare occurrence unless specimens are specially prepared to show them. In his Eocene Bryozoa Prof. Reuss ‡ figures and describes three species of *Spiropora*:—*S. tenuissima*, Reuss, having somewhat the general character of *Entalophora*; *S. pulchella*, Reuss; and *S. conferta*, Reuss. The Silurian species more closely resembles *S. pulchella* than the other two species of Reuss, both in the character and in the ordinary arrangement of the cells. It must not, however, be taken as evidence, satisfactorily settled, that the Palæozoic type blends naturally with the Oolitic and Tertiary types. This is not so. The evidence is

* Haime's 'Jurassic Bryozoa,' Genus viii. pp. 193, 194.

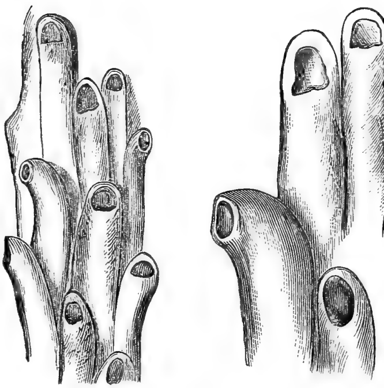
† In *F. plebeia*, M'Coy. In *Alecto frondosa*, James, the punctured pores are a marked feature.

‡ 'Tertiary Bryozoa of the Alps.'

only superficially exact; yet we have no other genus in which the type can be so conveniently placed as the genus *Spiropora*.

Locality. More or less abundant in the washings of the Buildwas beds, Wenlock Limestone, and in the shales over the Wenlock Limestone. Not frequent, but present in about the same proportion to the other fossils in the Niagara Limestone of Lockport as in the Wenlock Limestone, Dudley.

Figs. 7 & 8.—Spiropora intermedia, *Vine*.



7. The whole of the cells on the portion of branch selected for illustration: × 12. 8. Four cells from fig. 7 further enlarged, to show the various conditions of the cell-mouth: × 24.

8. Spiropora intermedia, sp. n. (Figs. 7, 8.)

Zoarium cylindrical, subcylindrical, club-shaped, branching or not. *Zoœcia* tubular when perfect—when worn, elongately oval or pyriform—adnate or free; orifice circular, raised or decumbent; peristome thick. Cells irregularly or spirally arranged, opening on all sides, and clustering in the thickened or club-shaped specimens without any definite order. Cells occasionally exserted and bent round. Generally speaking, two cells occupy the space of a line; but some of the exserted cells measure three quarters of a line in length.

Locality. Tickwood beds; in no. 25 washing only.

It is necessary, from the anomalous character of this species, to direct particular attention to the exserted cells in some parts of the zoarium. In this respect they present an appearance closely resembling that of *Entalophora*. Indeed, if I were dealing with Tertiary species of Polyzoa, such as the Montecchio Maggiore material, and found amongst the number a specimen having cells of a similar character to the one I am dealing with, I should not have the least hesitation in placing it under the genus *Entalophora*. In the Tertiary species, however aged the colony might be by calcareous incrustations, in some patch I should be able to detect the rugose markings or the punctures peculiar to this and other genera of the

Cyclostomata. In the Silurian species there is not the least indication of these markings or punctures.

Good specimens of the species are comparatively rare. I have only found about twenty specimens; and no two of these are exactly alike. Yet there is a general likeness in the whole group of specimens; and in the character and structure of the cell an easy comparison may be made with *Spiropora regularis*. It seems to me that the species I am now describing is to some extent an abnormal form, which has become constant within a very limited area, and taken the place of *S. regularis* in these beds, to some extent at least. I found a few small fragments of this last species in this and in another washing; but the specimens are true to the characters already ascribed to the species. It would perhaps be better to speak of *S. intermedia* as a variety of the other. In this case it would be necessary to have some indication that such was the fact; but of this I have no evidence, except that the non-exserted cells have a specific likeness in some parts of the zoarium. Both in the general habit and the characters of the two species they are individually and collectively distinct. *S. regularis* hardly ever varies either in the arrangement of the cells or in the mode of branching. This one varies considerably in the cell-arrangement; and the branching, when present, is different.

Locality. No. 25. Tickwood Beds.

9. Diastopora consimilis, Lonsd.

Aulopora consimilis, Lonsd. Silurian Syst. pl. 15. fig. 7.

Diastopora consimilis, Lonsd. Siluria, 1859, 3rd ed.

In plate 15. fig. 7, of the 'Silurian System,' Lonsdale placed amongst the corals the above species, leaving the genus as doubtful (*Aulopora*?) with the remark "probably a Bryozoon." His description of the species is:—

"Encrusting, tubes round, close together, radiated, bifurcated; opening circular, raised, margins thick."

"Similar to *Aulopora compressa*, Goldf., found in the Oolitic series of Germany. Locality and formation, Wenlock Limestone"*.

This comparison with the species of Goldfuss is very exact; and if I were dealing with an Oolitic *Diastopora* I should have little hesitation in confirming Lonsdale's reference.

In my British-Association Report on Silurian Polyzoa†, I have made a reference to Lonsdale's species, and I have also described a specimen submitted to me by Mr. Longe. Since this was written I have discovered a fragment of shell nearly triangular in shape, three and a half lines in breadth by three lines long, covered by a portion of what has apparently been a large colony. I have therefore made the following diagnosis from that fragment alone.

Zoarium of unknown dimensions, incrusting by a single layer a fragment of shell. *Zoœcia* tubular, regular, elongate, in series, the proximal end of the cell rather narrower than the distal; cells contiguous, but each separated by its own wall. Orifice circular;

* 'Silurian System,' descriptive text of pl. 15. † York, 1881.

peristome slightly raised and thick, which causes a slight constriction of the aperture of the cell. Measured as nearly as possible across the mouths, about six, or six and a half, cells occupy the space of a line; in a longitudinal direction about two and a half cells occupy the same space.

Locality. Buildwas beds (no. 40); Dudley Limestone, *Lonsd.*; ditto, *Mr. Longe* (descr. Brit. Assoc. Rep. 1881); Lower Ludlow (?), Ledbury *.

Affinities. It is a difficult matter to make any comparison with either Goldfuss's figures or description. On the supposition that the magnified figure (tab. 38. fig. 17, Petref. Germ.) of *Aulopora compressa* is enlarged about sixteen times, that would give for the natural size about two and a half cells to the line, a measurement in nearly every way similar to *D. consimilis.* As regards facies, there is a very close resemblance between the Silurian and the Oolitic species. In admitting so much, I do it with very great reluctance; but I cannot speak authoritatively without having the means of comparing the fossil described by Goldfuss. Independent of this, I know of no other species of Palæozoic Polyzoa, excepting the *Stomatoporæ* previously described, that bears so close a resemblance to the *Diastoporæ* of the Oolite. However we may be disposed to regard this association of types, either favourably or unfavourably, there can be no question that we have in *Diastopora consimilis* a true tubular *Diastopora*; and all the *Berenicea* type of Polyzoa in the Silurian, and even in the Carboniferous rocks, will have to be placed in a different genus. Apparently there is some slight resemblance between this species and *Alecto confusa*, Nich. (pl. 11. fig. 4 †). The specimen incrusting a coral in the cabinet of Mr. Longe (Brit. Assoc. Rep., Silurian Polyzoa, 1881) is very closely allied to Nicholson's species, much more so than the specimen described above. As I cannot, however, separate the specimens found in our Wenlock series, I think it best to allow the reference to remain upon record in the hope that some at least of the American palæontologists will be able to establish the affinity, if such be possible. There is, judging from material in my possession, a very close relationship between American Silurian and our own Wenlock species, not only in the Polyzoa but in species of the *Alveolites* and also of the *Monticulipora* types.

Ceriopora, Goldfuss.

1826. *Ceriopora*, Goldfuss, Petrifactions of Germany, pp. 33, 215.

This genus was established by Goldfuss; but it has been broken in upon by authors, and many of the species have been placed in other genera, such as *Alveolites* and *Monticulipora.* There are, however, species in the Silurian shales that evidently belong to the Polyzoa; and Milne-Edwards, in his 'Silurian Corals,' refers two species to this class. They are as follows:—

10. "Favosites? oculata, M'Coy, Brit. Pal. Fos. p. 21 (*Ceriopora*

* School-of-Mines Catalogue, p. 119.

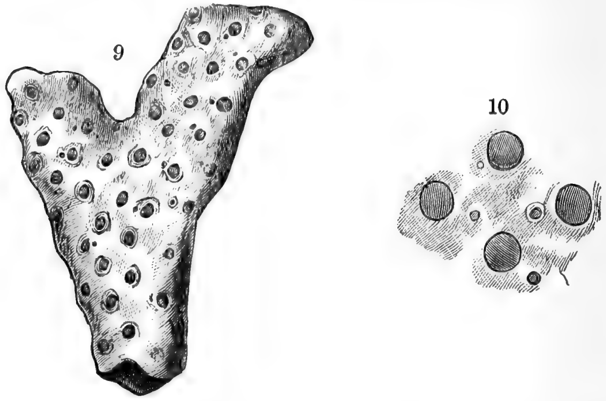
† Ann. & Mag. Nat. Hist., February 1875.

oculata, Goldfuss, Petr. Germ. vol. i. tab. lxiv. fig. 14), appears to appertain to the class Bryozoa."—*Silurian Corals*, p. 261 (1854).

11. "STENOPORA? GRANULOSA, M'Coy, Brit. Pal. Fos. p. 26 (*Ceriopora granulosa*, Goldfuss, Petrif. Germ. vol. i. tab. lxiv. fig. 13), is a fossil coral from Dudley, which appears to belong to the class Bryozoa."—*Silurian Corals*, p. 269 (1854).

In addition to the above, Milne-Edwards in reference to the genus *Cœnites* says:—"It is not without some hesitation that we place *Cœnites* in the class of Polypi, the form of the calices resembling very much what is met with in certain Bryozoa. In the present state of our knowledge concerning the structure of these fossils, their zoological affinities cannot be determined with certainty; but we are inclined to think that they are allied to the Favositidæ."—*Silurian Corals*, p. 276 (1854).

Figs. 9 & 10.—Hornera? crassa, *Lonsdale.*



9. Portion of zoarium: × 12. 10. Four cells enlarged, to show the position of a lateral secondary pore, which is sometimes placed on one, sometimes on the other side. Some few of the cells are without the secondary pore: × 37.

12. HORNERA? CRASSA, Lonsdale, Silurian System, pl. 15. figs. 13, 13 *a*.

Polypora crassa, 'Siluria,' Morris's Catalogue.

Polypora crassa, Cat. Cambrian and Sil. Foss. School of Mines.

"Branches short, thick, flat, dichotomosed; opening of cells large, elevated, and irregularly disposed on one side, opposite side striated. Internal structure not ascertained."

This is Londsdale's diagnosis of the above species, figured in the 'Silurian System,' and again in 'Siluria.' It is found in the Wenlock Limestone of Dudley. In the School-of-Mines Catalogue it is given as *Polypora crassa*, Lonsdale, and also as *P. crassa* in Morris's Catalogue; and as *Polypora* it is generally accepted by authors.

The genus *Polypora* was founded by M'Coy in 1844; and it is made to include Lonsdale's species as well as species described by the

author. M'Coy says:—"Interstices [branches] connected by thin, transverse, non-poriferous dissepiments" *. This is the distinctive feature of Carboniferous and Devonian species, but not of the type included in the genus found in the Silurian rocks and shales. The Silurian *Hornera*?, then, of Lonsdale, is clearly not a *Polypora*.

The genus *Thamniscus*, King, in the absence of fossils on which I could more safely rely, I cannot understand. If fig. 9, pl. 5, of his Permian Fossils, stood alone, I should have no difficulty in identifying *H. crassa*, Lonsdale, as a species of the genus *Thamniscus*, King: fig. 8 is a worn specimen; but that too is pretty clear. If, however, we are obliged to accept the anomalous characters depicted in figs. 10, 11, 12 as types also of the genus, then we have clearly to deal with more than one suborder. As at present understood, it is not wise to place the species described by Lonsdale in the genus *Thamniscus*, King.

In describing Carboniferous Polyzoa, Messrs. Young of Glasgow have placed in this genus a species † having a very peculiar branching. In doing this they must rely upon evidence that, unfortunately, I do not possess. I have therefore figured my best fragments in the hope that better specimens than I possess will be forthcoming, and that the characters of both the genus and the species may be redefined ‡.

Locality. Dudley, Tickwood beds.

I have several fragments of another very delicate species belonging to the same genus, whatever it may, in the future, be called; I cannot regard this delicate species as the same, even in a young state, as the one described by Lonsdale. I have fragments of both; and they differ in many particulars. I shall therefore temporarily place it in the same genus which Lonsdale gives.

13. HORNERA ? DELICATULA, sp. n.

Zoarium delicate and irregularly branching dichotomously, but not in one plane. *Zoœcia* disposed in diagonal lines, but rarely exceeding three; the marginal cells slightly indent the margin. Orifice of cells round when perfect, pyriform or oval when worn; peristomes raised, and the interspaces between the cells filled up apparently with wavy lines; but in section the cœnœcium is filled in the interspaces between cell and cell with minute pores. *Zoœcia* rather more separated, comparatively speaking, than in *H.? crassa*; and six cells occupy one line measured perpendicular to the base.

Locality. Basement beds of Buildwas beds, no. 22.

This very minute species is the smallest in individual character of all the Palæozoic branching Polyzoa with which I am acquainted. The character of the zoarium, the mode of branching, and general habit of the species is well shown. I have not found the larger

* Syn. Carb. Foss. of Ireland.

† *T. Rankini*, Y. and Y.

‡ Since this was written, I learn from Mr. Shrubsole, F.G.S., that in all probability he will be able to establish the genus *Thamniscus*, King, on a more solid basis than it rests upon at present. If so, then the species described by me as *Hornera? crassa* and *H.? delicatula*, Vine, may find a proper resting-place in the family Thamniscidæ, King.

species of Lonsdale in these lower beds; neither have I found any ally of the smaller in the higher beds. My fragments of both species show the mode of growth of *H.*? *crassa*; and also of *H.*? *delicatula*; and these are different in their origin and also in their mode of development.

14. Polypora ? problematica, sp. n.

I have in my cabinet several specimens of a most peculiar type; but whether to call it a Polyzoon or an Actinozoon is to me a puzzle. Salter was well acquainted with the organism; but I believe he left it unnamed amongst the Cambridge fossils.

Zoarium dendroid, with a strong base. *Zoœcia* on one side irregularly oval, contiguous, but having distinctly individual walls to each cell, though to all appearance the walls are inseparable: on the reverse of the zoarium spaces are striated, some of which striæ enclose a slightly elongated nucleus having a similar appearance to that found in the reverse side of species of *Hornera*. I am unable to associate it with any known species of *Phyllopora* or *Polypora*.

Localities. Buildwas beds and Tickwood beds.

Fenestella, Lonsdale, 1839.

15. F. prisca, Lonsdale.

F. Londsdalei, d'Orb. of authors.

This genus has been ably reviewed and revised by Mr. G. W. Shrubsole, F.G.S., in three papers read before the Geological Society*. In his paper on British Upper Silurian Fenestellidæ (May 1880), the author writes very correctly about *F. prisca*, Lonsdale. From the details and figures furnished by Lonsdale it is impossible to form a correct idea respecting this species; and d' Orbigny seems to have added but little to the details after changing the name. So far as these authors are concerned, Mr. Shrubsole did perfectly right in striking this, with others, off the list of our described *Fenestellæ*. I have, I have not the least doubt, specimens of the species described by Lonsdale as *F. prisca*, and figured as such in pl. 15, 'Sil. System.' The specimens are about the same size, 15^a 15^b; but they are so incrusted by coral growth that I am not at all surprised that both the coral growth and *Fenestella* growth should form parts of the diagnosis of Lonsdale. When any part of the zoarium is free from the parasite, the real number of cells on each side of the fenestrule is three. These are separated by a keel which looks like a dark line passing along the centre of the branch. The dissepiments are deeply set; but the most characteristic feature is, for a specimen so small, the strongly-rooted base. The described species of *Fenestella* which form the substance of Mr. Shrubsole's second paper are from Wenlock Limestone. My specimens are from No. 25, Tickwood beds, of the Wenlock Shales. So very scarce are even fragments of *Fenestella* in these shales that I cannot forbear giving the specimens I have found prominence in this report on the organisms of the Wenlock Shales.

* Quart. Journ. Geol. Soc. May 1879, May 1880, May 1881.

GLAUCONOME, Goldfuss, 1826.

In 1849 Mr. King very wisely discussed the impropriety of accepting the *Glauconome* of Goldfuss as a genus of Palæozoic Polyzoa. He says "the genus was typified by a Tertiary-like *Cellaria-salicornia G. marginata* . . . . . In this case the name *Glauconome* becomes obsolete." To take in such forms as *Retepora pluma* and the *Glauconome* of M'Coy, Mr. King founded the genus *Acanthocladia*. Seeing that the type *G. disticha*, Goldfuss, was accepted by Lonsdale, and has since been generally accepted by authors, and not the *G. marginata*, Münster, it seems to me that *Glauconome* ought to keep its place in our literary history. *Acanthocladia* too is neither a Silurian nor a Carboniferous typical genus. It is applicable for Permian, not for earlier types.

1839. Restricted by Lonsdale, 'Silurian System.'

This genus founded by Goldfuss, was originally intended for species of *Cellaria* which were figured and described by Münster in the Petr. Germ. tab. 36. figs. 5 to 8. The placing under the generic description a species of Silurian Polyzoa by its author is sufficient to redeem it from oblivion. The diagnosis, as furnished by Goldfuss, is useless; and we are obliged to accept the restricted definition originally given by Lonsdale, but somewhat modified by M'Coy.

"Zoarium strong, thin, laterally branched, bearing longitudinally disposed cells. Branches not united by transverse dissepiments: reverse striated."

16. GLAUCONOME DISTICHA, Goldfuss.

Zoarium branched, the branches diverging nearly at right angles, both from the central stem, and from the lateral branches: four rows of long quadrangular cells on one side, the opposite side striated. ('Sil. System,' pl. 15. fig. 12.)

The above is Lonsdale's description of the specimens found in the Wenlock Limestones. The description of Goldfuss is somewhat different; but the types described by the two authors are the same (Petr. Germ. pl. 65. fig. 15, p. 217).

This species is present, but not very widely distributed, in the shales. In the Tickwood beds, in the washing marked 25, it is rather plentiful; but fragments are not what may be called abundant even here. The only other shales in which I have found any quantity of specimens are 24 and 46; and these are washings of shales from over the Wenlock Limestone.

PTILODICTYA, Lonsdale.

1839. *Ptilodictya*, Lonsdale, 'Silurian System,' descriptive text of pl. 15.

This genus was founded by Lonsdale for a most peculiar group of Polyzoa which were very widely distributed in the Silurian rocks, and survived in some places even into the Devonian. The type of Lonsdale's genus is a *Flustra* of Goldfuss; and his species is found in the Wenlock Limestone.

17. Ptilodictya lanceolata.

Syn. & ref. *Flustra lanceolata*, Goldf.
Ptilodictya lanceolata, Lonsd. Sil. Sys. pl. 15. figs. 11–11 *e*.

Zoarium long, narrow, flat, slightly curved longitudinally, and thin, gradually diminishing to a fine edge; middle cells narrow, small, in about ten rows; lateral cells larger and arranged in rows slightly arched from the middle to the edge; the cells themselves placed obliquely both with respect to the middle of the zoarium and the arch*.

Locality and Formation. Wenlock Limestone, Dudley.

This type species of the genus is a very fine one; but it is questionable whether all the small fragments are referable to this species. Lonsdale himself had his doubts; for he says "fragments of probably young specimens are occasionally found in the Wenlock Limestone."

In the 'Wenlock Shales' localities will be given. I have found a number of fragments of two species of this genus. By far the largest numbers of these fragments I am unable to identify with the description or figures given by Lonsdale; yet I have not the least doubt that these are the *Ptilodictya lanceolata* of authors, and also of the Catalogue of Cambr. and Sil. Foss. in the School of Mines. From the Upper Llandovery to the Wenlock Shale, Mr. Newton gives three references—two to *Ptilodictya lanceolata*, Lonsd., and one to *P. scalpellum*, Lonsd. As no other references are given, I think I may fairly conclude that these specimens of the Shales would ordinarily be referred to *P. lanceolata*, Lonsd. There is, however, a considerable difference between the Wenlock species and this. Under these circumstances it will, I think, be better to rename and redescribe one of the two species found in the Shales.

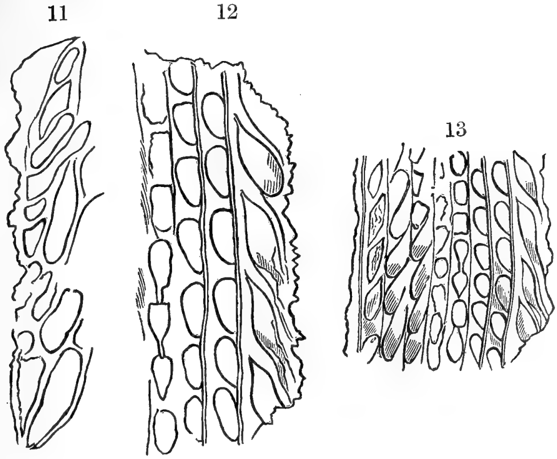
18. Ptilodictya lonsdalei, sp. n. (Figs. 11–13.)

P. lanceolota of authors: "young specimens," Lonsd.

Zoarium thin, when full-grown lance-like, one edge of which is slightly convex: base rooted (?) either to some foreign object or to a parent zoarium; margins non-celluliferous, but not solid, composed of a loosely compacted "endocystal" layer. *Zoœcia* on both sides, separated, but not by a laminar axis?; the rows of cells divided by bars which bifurcate at intervals. Two rows of cells, rather longer than wide, occupy the central area, giving off on each side from two to seven laterally oblique rows. This character is only seen in sections: externally all the rows of cells, from four to sixteen, appear to be longitudinally placed. Aperture of zoœcia ovate, and nearly as large as the subtubular cells. About six zoœcia occupy the space of a line measured longitudinally; and about eight rows, including the bars, occur in the same space in a transverse direction. At the distal corners of all the cells there are small openings, ranging in character from circular to ovate, especially towards the margins of the zoarium. This is one of the most constant characters of the species.

* Lonsdale, 'Silurian System,' descriptive text of pl. 15, slightly altered.

Figs. 11–13.—Ptilodictya Lonsdalei, *Vine.*



11. Section nearly parallel to the central axis, showing the marginal cells, and the compressed perpendicular cell: × 20.
12. A portion of the same, further enlarged: ×40.
13. A portion of the non-poriferous margin of another section: × 40.

Localities. Though rare in some of the washings, more or less abundant in all the shales below the Wenlock Limestone. Very rare, though I have found a few fragments, in the shales No. 46 over the Wenlock Limestone.

Affinities. This species resembles to some extent *P. flagellum*, Nich. (Ann. & Mag. Nat. Hist. March 1875, pl. xiv. figs. 3, 3^b), except in the flexuous character of the base. There is a slight difference in the measurements of the two species; and Nicholson does not allude to any distal openings, while these are a marked feature in *P. Lonsdalei*. I have not specimens for comparison; but I have not the least doubt that it will be found that the Llandovery and Wenlock *P. lanceolata* may be placed here. My only objection to describing the fragments as typical of Lonsdale's species is that the Wenlock Limestone type is altogether different and considerably larger. Under these circumstances I dedicate the species to Lonsdale's memory.

In the description of this type I have indicated the function of the "non-poriferous margins" of *Ptilodictya* by speaking of them as the "endocystal layers." Taking the endocyst and the ectocyst together, the latter being only a structureless excretion from the endocyst charged with a protective function *, it may be well to direct attention to this physiological feature. I have ascertained that the enlargement of the colony of *Ptilodictya* takes place at the distal openings and also at the margins. After a time enlargement at the distal openings becomes abortive, and these indications of a function remain as ornaments only. It is different on the margins; here life is more active, and enlargements take place on the younger por-

* Hincks's Brit. Mar. Polyzoa, p. x.

tion of the growing colony; but even here it seems to me that much of this marginal growth also becomes abortive after a time, and it, too, remains as ornament. It may be wise to extend these remarks so as to elucidate facts connected with the zoarium of other species as well; but this would be out of place in a general paper. I have referred to the subject for the express purpose of drawing to it the attention of biologists and palæontologists. I refuse to say cells "separated by a thin laminar axis" because this is not so in this species at least. The "axis," if such it may be called, is formed by the bases of the cells, both in transverse and in longitudinal section. I have it on the authority of Mr. John Young of Glasgow that some of the rough fractures of *Ptilodictya* from the Scottish Silurian Series show the wrinkled septal layer which intervenes between the two layers of cells. There are also specimens in the School of Mines which show the same wrinkled aspect; and Professor Nicholson makes a point of showing this septal layer in nearly all his species. This being a matter of extreme importance, I shall return to its discussion at some future time when other investigations which I am making are completed.

19. Ptilodictya scalpellum, Lonsdale.

Eschara scalpellum, Lonsd. Descriptive Text of Sil. Syst. pl. 15. figs. 25–25 *a*, p. 679.

Zoarium lancet-shaped. *Zoœcia* more or less oval, nearly opposite on the two surfaces; outer rows, cells smaller and more distant than in the other rows: edge of zoarium, when perfect, solid, faintly striated and sharp; outer covering and opening of cells unknown.

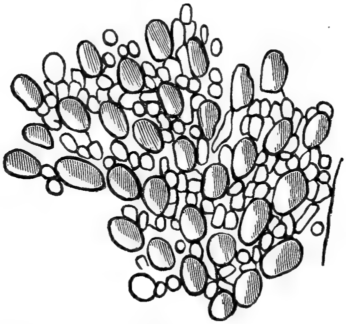
Locality and Formation. Wenlock Limestone, Dudley.

The above is a slight modification of Lonsdale's description of *Eschara scalpellum*, which, by general consent is placed in the genus *Ptilodictya*. In his remarks he says that his species "is placed in the genus *Eschara* on account of the apparent thickening of the surface of the outer cells, and the cells being nearly opposite on the two sides. In some specimens the thickening of the surface of the outer row is so great as nearly to obliterate the opening of the cells."

I have copied nearly the whole of Lonsdale's diagnosis and remarks, on account of the minute details which he gives. I am not acquainted with specimens from the Wenlock Limestone, Dudley; and the Upper Llandovery specimen in the School of Mines is only a cast. The several fragments which I have found in the shales undoubtedly belong to this species. One character of the genus *Ptilodictya* is present; otherwise there would be a difficulty in placing it in the genus. This is the divergent arrangement of the outer cells obliquely from the middle longitudinal cells. As Lonsdale says, there is around the openings such a mass of thickening material that the true area cannot be seen to advantage. The margins of the zoarium are solid; and in sections the structure is different from that of *P. Lonsdalei*. Not having other species of a similar nature to compare it with, I leave it temporarily with *Ptilodictya*.

Localities. Buildwas beds, No. 38 only; Coalbrookdale beds, very rare fragments; Tickwood beds, No. 25 and No. 42.

Fig. 14.—Ptilodictya interporosa, *Vine.*



A portion of the branch of one specimen, showing the central and lateral arrangement of cells with the intercellular spaces filled with smaller openings: × 12.

20. Ptilodictya interporosa, sp. n. (Fig. 14.)

Zoarium consisting of a thin, narrow, branching frond of unknown extension. *Zoœcia* arranged in two orders; the median row, or rows, may or may not be perpendicular to the base, and may consist of from one to four rows; for this character is very variable: the lateral rows are oblique, extending to the margin of the zoarium, which is rather sharp-edged, but without any marginal striæ: cells oval, slightly compressed in the middle, rather larger towards the margin. The whole of the cells are surrounded by minute openings ("interstitial tubules"*) which, becoming filled in, in the older growth of the colony present the appearance of a minutely granular peristome to the cell. About four cells, with their "interstitial tubules," occupy the space of a line in either a longitudinal or oblique direction, and about six transversely. The compressed character of the median rows in one specimen alters this measurement slightly; but the clearly defined character of the cells of this species is unmistakable.

Locality. Tickwood beds, No. 42.

This beautiful species is founded upon ten fragments, the longest of which is not more than a quarter of an inch in length. The characters, however, are so distinct and so unlike those of any other *Ptilodictya* that I know of, that I cannot do otherwise than describe it as new. At first sight the specimens may be mistaken for a *Fistulipora*, M^cCoy; but although hundreds of fragments of *Fistulipora* are found in the same beds, only the ten specimens of this, as abovenamed, have been found. The orifices of the cells of *P. interporosa* are distinctly oval; in *Fistulipora* they are circular; and in the zoarium of this latter species there are non-cellular spaces which are filled in with interstitial tubuli of a most marked character. In

* Of Nicholson.

P. interporosa there are none of these spaces: there are single rows surrounding each orifice, very rarely more; but occasionally the rows are double in some few of the interspaces. Again, none of the cells of *Fistulipora* are arranged in series; in the species described above they are distinctly serial, either perpendicularly or obliquely.

Ptilodictya cosciniformis, Nich. (Geol. Mag. 1875), is the only species with which I can compare *P. interporosa*; but in size and habit the American species is so different from our own, that there seems to be no natural affinity between them. Again, the species described by me has only four cells to the line; in Nicholson's species six or seven cells, measured diagonally, occupy the same space. And although in *P. cosciniformis*, Nich., "the interspaces left by the opposition of the oval cell-mouths are entirely filled by very minute interstitial tubuli," there cannot be any possibility, even in fragments, of confounding one with the other.

21. Ptilodictya, sp.

I have a few fragments of another well-marked species, but not in such a state of preservation as will allow of detailed description. Still, if I describe it to the best of my ability, it may be that other workers may recognize the type and in their researches obtain better specimens than I can boast of.

Zoarium a thin flattened frond of unknown dimensions. *Zoœcia* arranged in two series, but with no distinct median row or rows. The two series seem to rise from a common point, then bending, one series to the right, and the other to the left, with a slight curve. Orifices of the cells very minute; ten of them occupy a line.

Locality. Tickwood beds, No. 25.

If this species has not been previously described, I would suggest for it the name of *Ptilodictya minuta*.

Other very doubtful species of Silurian Polyzoa which I have found in these Shales I shall have to rework. At the present time I cannot do more than say that there are still a few undescribed forms left.

I have endeavoured, in the above paper, to give as few microscopical details as possible, because these seemed to me to be rather out of place. I cannot, however, let the paper pass beyond my control without saying that every species recorded has been examined macroscopically and microscopically. The sections prepared have revealed many unexpected features that will help to throw some light at least upon the development of the Polyzoa generally, and upon the biological history of the Silurian Polyzoa in particular.

5. *On the Genus* Stoliczkaria, Dunc., *and its Distinctness from* Parkeria, Carpenter. By Prof. P. Martin Duncan, M.B.Lond., F.R.S., F.G.S., Pres. Royal Micr. Soc. (Read November 2, 1881.)

[Plate II.]

The last scientific work of Stoliczka, whose name will be always associated with the palæontology of India, was performed during the return of the second Yarkand expedition. A few days before his death he crossed the Karakoram Pass, and, travelling on, traversed the last geological scene he ever described. He wrote in his journal:—"At last we descended into a narrow gorge, the sides of which, for fully a mile, consisted of a limestone conglomerate, the boulders of white, grey, or black limestone being well rounded and worn, and cemented together by a stiff bright red clay. Upon this followed dolomitic limestones, rather indifferently bedded, massive and white; and these were overlain by bluish shales and well-bedded limestones extending from about six miles north of Burtri to the camp. The limestones appear to be Triassic; they are compact, with layers full of small Gasteropods, among which I noticed a *Nerinæa.* The so-called 'Karakoram stones' occur in dark shales below the limestones, which are capped by a yellowish-brown limestone, well bedded, but of unascertained age. The whole series dips north-west at a moderate angle"*.

It is to a group of the Karakoram stones that I venture to draw the attention of the Society.

The stratigraphical position of the stones is lower than the Lias; and they may be Rhætic or Triassic in age.

The stones had been objects of curiosity in India for many years before their exact locality was discovered; and their spherical and spheroidal shapes had attracted much attention. A specimen was given to this Society many years ago by Col. Godwin-Austen, F.R.S., and is in our museum. No careful examination of any of the numerous forms of the spherical stones was made, however; and in 1878, Mr. W. T. Blanford, F.R.S., asked me to investigate the fossils, and to write their description in a memoir, which was to be included in the 'Scientific Results of the Second Yarkand Mission.' My work was completed and the book was published in 1879.

The Karakoram stones were, after as careful an examination as I could give them, placed in the class Rhizopoda, in a new order, the Syringosphæridæ; and the typical form was placed in a genus *Syringosphæria.* Five well-marked species were described as belonging to this genus.

A very large specimen, the only one of its kind, was not cut into; nor were microscopic preparations made of it. But subsequently,

* See extract from Stoliczka's last diary, 'Scientific Results of the Second Yarkand Mission,' Karakoram stones, page 2: Calcutta, 1879.

and in time for publication, sections of it were made; and it then became evident that, had I attacked this specimen first of all, many of the very considerable difficulties which attended the investigation of the whole group would have been lessened. This large spheroidal specimen turned out to be one of the Syringosphæridæ; but its structures did not come within the generic idea of *Syringosphæria*. Its structure was remarkably simple, and presented many microscopic beauties of detail.

The form was placed in the new genus *Stoliczkaria*.

Some time after the book to which I have already referred was published, doubts were entertained whether the Karakoram stones were separable from that group of great spherical and spheroidal Foraminifera embracing the genera *Parkeria* and *Loftusia*, which was so ably described by Dr. Carpenter and Mr. Brady in the Phil. Trans.* vol. clix. pt. ii. The shape of many of the specimens of the Syringosphæridæ was noticed to be the same as that of *Parkeria*; and the similarity of the external ornamentation was in some instances very great, to the naked eye.

Although the distinctness of the Indian and English forms was always evident to me, and the non-arenaceous nature of the inner parts of the Syringosphæridæ was without doubt, I felt the necessity of very carefully reconsidering my work and decisions, especially as specimens of *Parkeria* have been lent me by Prof. H. G. Seeley, F.R.S., and Dr. Millar, F.G.S., the fossilization of which is mainly calcareous, and as in some of the doubtful fossils interspaces exist.

The following are the diagnoses of the order Syringosphæridæ, and of the genera *Syringosphæria* and *Stoliczkaria*.

Order SYRINGOSPHÆRIDÆ.†

Body free, spherical or spheroidal in shape, consisting of numbers of limited more or less conical radiating congeries of minute, continuous, long, bifurcating and inosculating tubes; also of an interradial close or open tube-reticulation arising from and surrounding the radial congeries. Tubes opening at the surface on eminences and in pores, and ramifying over it. Tubes minute, consisting of a wall of granular and granulo-spiculate carbonate of lime. Cœnenchyma absent.

The presence of pores on the surface of some forms of the order, and their absence in others, and the nature of the interradial reticulation in the poreless kinds, necessitate the division of the order into two genera.

Genus SYRINGOSPHÆRIA.

Body large, symmetrical, nearly spherical or oblately spheroidal, covered with large compound wart-like prominences with intermediate verrucosities, or with compound monticules having rounded

* "Carpenter and Brady on two gigantic Types of Arenaceous Foraminifera," p. 721, vol. for 1869. *Parkeria* and *Loftusia*.

† 'Scientific Results of the second Yarkand Mission' (published by order of the Government of India, Calcutta 1879), page 10.

summits, with solitary eminences between them, or with close broadly rounded tubercles, or with minute granulations. Rounded or oblique or linear depressions occur on the surface, usually between the eminences, but sometimes upon them; they are shallow and are bounded by tubes, some of which open on their floor. The surface has tubes opening on it from the internal radial series, and also from the interradial tube-reticulation; also masses of tubes running over it, converging on the eminences, and more or less reticulate elsewhere.

Radial congeries of tubes numerous and defined; and the interradial tubulation is open or close and varicose.

Genus Stoliczkaria.

Body very large, symmetrical, oblately spheroidal, covered with a great number of minute distinct granulations, which are circular at the base, short and rather flat where free, and which are separated by an amount of surface about equal to their breadth. No pores exist. Tube-openings occur on the granulations; and tubes, with or without openings, converge to their surface and cover the intermediate surface. The tubes opening onto the centre of the surface of the granulations are terminations of the very numerous radial series, and are small; and the others, which are larger, belong to the closely packed varicose and much contorted interradial series. The body within consists of a vast number of small, not very conical, but rather straight, radial series, whose rather distant tubes give off minute offshoots to the surrounding convoluted and varicose large tubes of the close interradial series. No cœnenchyma can be discovered.

The species *Stoliczkaria granulata*, mihi *, is characterized by having a symmetrical spheroidal body, and by the minute eminences on it giving a granular appearance to the whole. These low granulations (Plate II. fig. 1) are usually circular in outline, and flat normally at the free end, and they merge into the substance of the periphery at their base. They are about $\frac{1}{100}$ inch in breadth, and may be of the same height. Sometimes the bases of several are continuous, and a ridge is formed. In a few places the granulation is absent; but a circular marking denotes its former position. Rather large tubes are on the outside and flanks of the granulations, and they open at the top all around a central portion. This inner or central part of the projection shows the ends of a few small tubes and much space occupied by infiltrated calcareous matter. The large outer tubes pass downwards onto the surface of the body between the projections, and dip into it and are surrounded by a number of open tube-ends and occasional tube-reticulation. When a projection has been worn off, the central small tubes are still seen on the surface to be surrounded by a ring of larger ones; and between the positions formerly occupied in this manner there are spaces full of the ends of large tubes passing from within outwards (Plate II. fig. 2).

Sections of the body, made tangentially, show a number of small,

* *Op. cit.* p. 16.

separate, circular or stellate structures surrounded by a dense tubulation, which may be convoluted here and there.

The circular structures are continuations of the granulations; or rather the granulations are the ends of the circular systems. In the section the central space of each system is occupied by from four to six or seven small tube-openings and by clear calcite. These small tubes, the terminal openings of which are seen on the tops of the granulations, are about $\frac{1}{750}$ inch in diameter. They are connected together by a few small tubules which stretch across the space now filled with calcite; and they also give forth tubes which open into geniculate or elongated processes of the larger tubes of the interradial series environing them. The surrounding, large, interradial tubulation is very distinct; and the circular openings produced by sections of the tubes are from $\frac{1}{250}$ to $\frac{1}{190}$ inch across. Outside of the circular ring of the system is a mass of these tube-openings and tube-bendings; and the tubes communicate with larger long and short tubes and with those forming the circular ring. The sections of some of the tubes of this circular ring present a flask-shaped outline, the projection being inwards, and it ends in a tube which joins a small inner tube of the radial series. (Plate II. fig. 2.)

Radial sections present a totally different appearance. Made close to the surface and implicating rows of the projections, the small tubulation, distant and surrounded by calcite, is noticed to run up in a radial direction through the body into the middle of the projections. This radial system of tubes is very distinct; and on either side are the much larger tubes, either straight in their course or greatly convoluted, close, inosculating and bifurcating frequently. These tubes form the wide interradial systems, and reach the surface, some on the flanks of the projections, and others on the intermediate surface. (Plate II. figs. 3, 4, 5.)

The radial direction of each individual interradial tube is most distinct near the surface.

Radial sections made nearly halfway through the fossil show this same repetition of radial and interradial parts. The general appearance is of numbers of radii of minute tubes surrounded by wider radii of large and contorted tubes, the radii, of course, converging to the centre.

It is evident that the tubes of all kinds increase in number from the centre to the circumference of the body by frequently repeated bifurcation; and hence the number of systems increases.

The tubes are bent, often at right angles, and sometimes seem to terminate in blind ends; but there is always a connexion close by with a neighbouring tube. The radial and interradial tubes are well separated throughout; but occasionally a large tube transgresses on the central space, and some small radial tubes are double their normal size. (Plate II. figs. 4, 5.)

The continuity of the tubes from the centre to the circumference is undoubted. Clear or slightly coloured calcite is seen between the tubes; but it is structureless, and no cœnenchyma appears to have existed. The structure of the tube-wall is very minutely granular, and

is of carbonate of lime. A slight organic residue is left after treating with strong hydrochloric acid; and a ferric oxide is also present.

Here and there only, and not universally, interspaces occur. They are elongate, narrow, almost structureless parts; and they occur in the position elsewhere occupied by the small radial tubes or in that of the interradial tubes.

Some of these spaces are filled with drusy-looking carbonate of lime, which polarizes well; and others contain towards the centre of the whole body a projection which resembles broken-down tubes. In some there are indications of tubes passing along the sides of the space.

The height of the body of the type is $2\frac{3}{10}$ inches, and the breadth is nearly 3 inches.

In comparing this form with *Parkeria*, it is necessary to consider the anatomical characters given by Carpenter and Brady of the interesting fossils from the Cretaceous rocks. For in external appearance (but not in structure) the Syringosphæridæ resemble the genus *Parkeria*. The spherical and spheroidal shapes are common to both groups; and so are the granulate, plain and mulberry-like outer configurations.

In *Parkeria* there are a radial series of large and often solitary tubes, a system of interspaces in concentric series, and a labyrinthic structure of irregularly shaped chamberlets communicating with each other and cancellous in appearance, and occasionally simulating short tubes.

The interspaces are traversed by one or more large radial tubes; and the floor of each interspace towards the centre of the body is made up of the minute chamberlet structure, the openings of which communicate with the interspace beyond, but not with that nearer the centre. The labyrinthic structure sometimes stretches across the interspaces, and in many places forms a layer around the radial tubes. These tubes open at their sides, and communicate with the labyrinthiform chamberlets of the lamellæ forming the floor and roof of the interspaces, and are much larger in their calibre than the chamberlets which may here and there cover them.

There is therefore a defective continuity, from the centre of the body to the circumference, of radial tubes, and also a labyrinthic structure of a cellular and semitubular character.

The distinctnessof the morphology of the two genera *Stoliczkaria* and *Parkeria* is therefore evident.

The only parts which are analogous in position are the radial tubes and the interspaces.

The important labyrinthic structure is wanting in the Indian forms.

With regard to the radial tubes, they are minute and numerous and in systems in *Stoliczkaria*, and are surrounded by interradial tubes, which are larger and which are greatly convoluted but ever tubular. In *Parkeria* the radial tubes are comparatively few in number, one exists by itself, and there is no accompanying tube-structure like that of *Stoliczkaria*. The labyrinthic cells, assuming

here and there a tubular form, are much smaller than the radial tubes, around which they sometimes, but not invariably, reach. Hence in tangential sections the stellate appearance presented by *Stoliczkaria* is due to a number of circle-systems, each of which has a centre containing the cut ends of many small tubes, and of an environing circle of sections of much larger tubes, all intercommunicating. And in *Parkeria* the irregular appearance of canals in similar sections is due to sections of large radial tubes, one in each circle, each tube being surrounded by much smaller and irregularly shaped sections of cells and labyrinthic structure.

In *Stoliczkaria* the interspaces are not universal; and careful observations tend to the belief that they have nothing to do with the primary condition of the body, and that many depend upon the process of fossilization, and the rest upon the method of growth of the tubular structures.

In fact the Syringosphæridæ are composed of tubes starting from the centre of a body and radiating to the circumference, without any Foraminiferal structure. The tubes are of two kinds:—one which leads a straight course, and whose calibre is small; and the other is intermediate, highly convolute, and the calibre is larger.

Clearly the Syringosphæridæ formed the calcareous tubes organically, and they are not comparable with arenaceous Foraminifera.

EXPLANATION OF PLATE II.

Fig. 1. The granulations on the surface of *Stoliczkaria granulata*, Dunc., magnified 45 diam.
2. A tangential section, magnified 50 diam.
3. A radial section, magnified 50 diam.
4. } Interradial tubes, magnified 100 diam.
5. }
6. A diagram of the disposition of the tubular structures, nat. size.

DISCUSSION.

Prof. SEELEY thought that the difference between *Stoliczkaria* and *Parkeria* was one of mode of growth rather than of structure. He felt doubt as to the affinities of these organisms. He was inclined to regard *Parkeria* as showing affinities both with the Sponges and the Foraminifera. He thought that the analysis of *Stoliczkaria* served to throw doubt on the conclusion that *Parkeria* was originally composed of phosphatic grains. He was inclined to believe that both *Stoliczkaria* and *Parkeria* were originally calcareous organisms.

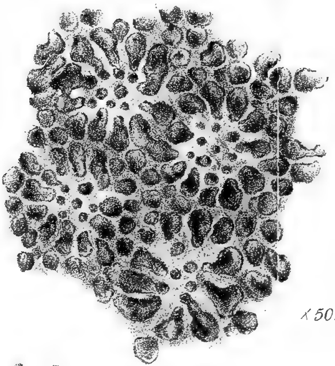
Mr. TAWNEY asked if Dr. Duncan had considered the possible alliance of these fossils with *Hydractinia*.

The AUTHOR admitted that it was a difficult question whether *Parkeria* was originally calcareous or phosphatic. With regard to its zoological position, it differed from sponges in having no *spicules*, and had little in common with any of the known forms of sponge. With regard to affinities with the hydroids, in spite of superficial resemblances there were remarkable differences. He did not place these forms among the Foraminifera; but he regarded them as certainly belonging to the great group of the Rhizopoda.

1.

× 45.

2.

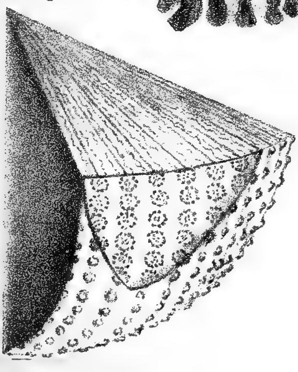


× 50.

3.

× 50.

6.



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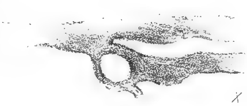

× 100.

5.

× 100

A. S. Foord. del.

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STOLICZKARIA GRANULATA.

6. *The* Zones *of the* Blackdown Beds, *and their* Correlation *with those at* Haldon, *with a List of the* Fossils. By the Rev. W. Downes, B.A., F.G.S. (Read December 7, 1881.)

Living, as I do, almost at the foot of the Blackdown Hills, it has naturally been my aim and ambition to add something to our knowlenge of their much discussed and highly fossiliferous strata. For some time I almost despaired of achieving any thing. The absence of good sections, the great difficulty (not to say, very often, the impossibility) of seeing the fossils *in situ*, the fact that all the pits but a very few are now closed, and the confused and unsatisfactory way in which the fossils have often been collected in past times, make the subject at the present time a very tangled skein indeed.

Collectors of Blackdown fossils have almost without exception, and perhaps unavoidably so, bought their specimens from quarrymen. And this means, generally speaking, that a quarryman who has "happened on some shells," has brought them home, and put them into a drawer or bucket or some such receptacle. Another find from another zone is the next day thrown in with them, and so on, until a sufficient quantity has accumulated, when the whole are thrown promiscuously into a hamper and sent to the address of the buyer.

Nor is this the only element of confusion. In days gone by a far more extensive interpretation of the term "Blackdown" seems to have been in vogue than would now be admitted. Even Dr. Fitton avowedly places specimens from "Lyme Regis" and "Beer Head" among his Blackdown list. Any thing Cretaceous—in fact, from beneath the chalk, in the borders of Devon and Dorset, ran a risk of being localized as "Blackdown." And that I am not exaggerating the confusion thus caused may be gathered from the following facts:—It will be readily admitted by all who have studied the subject that no true Blackdown fossil is calcareous; and yet I have scarcely anywhere visited a provincial museum (not excepting that at Bristol, in which Dr. Fitton's original specimens lie, and which contains what is, in other respects, a very valuable collection of Blackdown fossils) in which I have not found calcareous fossils labelled "Blackdown." Thus again and again do a few manifestly misquoted specimens discredit to some extent the localities of the remainder.

In 1880 I found that notes, correspondence, and memoranda had accumulated to such an extent that I determined to reduce to order the facts and information which I had collected. This I did in a paper entitled "Blackdown," published in the Report for that year of the Devonshire Association for the Promotion of Science, Literature, and Art. I then acknowledged my great indebtedness to many correspondents and helpers (an acknowledgment which I desire here and hereby to repeat). The paper, however, had not been long in print before I began to discover that there were some errors and

omissions* in it which required to be corrected or supplied, while at the same time fresh facts began to accumulate. I purpose therefore in the present paper to bring forward in part the same subject, but, it is hoped, dealt with more accurately and fully.

In addition, moreover, to the compilation of a list of Blackdown fossils from those scattered about in collections and Museums, the attempt will be made in the present paper to refer them severally to the zones to which they belong, so far as this has proved to be practicable, and to compare the zones thus identified with similar zones at Haldon, in so far as a similarity exists.

Literature of the Subject.

The literature more or less bearing upon the subject of Blackdown is very voluminous; and it is possible that some of it may have escaped me. The following works, however, have been consulted, and more or less referred to.

Dr. Fitton (1836). "On the Strata between the Chalk and the Oxford Oolite in the South-east of England." Trans. Geol. Soc. ser. 2. vol. iv. p. 233.

De la Beche. 'Geological Report on Cornwall, Devon, and West Somerset.' 1839, pp. 240–7.

De la Beche. 'On the Chalk, and Sands beneath it, in the Vicinity of Lyme Regis (Dorset) and Beer (Devon)." Trans. Geol. Soc. ser. 2. vol. ii. p. 114.

R. A. C. Godwin-Austen (1842). "On the Geology of the South-east of Devonshire." Trans. Geol. Soc. ser. 2. vol. vi. p. 433.

Renevier (1856). "On the Lower Greensand and Blackdown Fossils of England." Summary of original paper in Quart. Journ. Geol. Soc. 1856.

Briart et Cornet (1870). "Description &c. de la Meule de Bracquegnies." Mém. cour. par l'Académie R. de Bruxelles, tome 34.

Ed. Parfitt, 1870. "Fossil Sponge Spicules in the Greensand of Haldon and Blackdown." Report and Trans. of the Devon Association.

H. J. Carter. 'On Fossil Sponge Spicules of the Greensand compared with those of existing Species.' 1871.

C. J. A. Meyer. "On the Cretaceous Rocks of Beer Head, and the adjacent Cliff-sections, and on the relative Horizons therein of the Warminster and Blackdown fossiliferous Deposits." Quart. Journ. Geol. Soc. 1874.

J. S. Gardner. Many papers on the Cretaceous Gasteropoda, Geol. Mag. and Quart. Journ. Geol. Soc. 1875 to 1880.

Barrois. 'L'âge des couches de Blackdown (Devonshire)." Ann. de la Soc. Géol. du Nord, 1875.

Prof. P. Martin Duncan. "On the Upper-Greensand Coral Fauna of Haldon, Devonshire." Quart. Journ. Geol. Soc. 1879.

F. G. Hilton Price. 'The Gault, a Lecture.' 1879.

W. Downes. "Blackdown." Report and Trans. of the Devon Association, 1880.

* Notably the mention of Mr. Caleb Evans's collection was omitted.

The large majority of the above writers deal prominently with the question of the age of the Blackdown and Haldon beds. It will be well therefore, before proceeding further, to sum up the opinions which from time to time have been expressed.

The Age of the Beds.

It appears that De la Beche (Trans. Geol. Soc. ser. 2. vol. ii. 1826) and (Ordn. Survey Report, p. 237, 1839) classified them as Upper Greensand.

Fitton (1836) calls them Lower Greensand.

Godwin-Austen (1842) described them as possibly a sandy condition of the Gault.

Meyer at first maintained (1863, 1866) that they were Lower Greensand, but subsequently to some extent changed his opinion; and I gather from his later paper (1874) that he is somewhat disposed to assent to an opinion which had been expressed by Mr. Etheridge, who, mainly on the evidence of the Black-Ven section near Lyme Regis, places them on the horizon of the Gault; but he still thinks that some part may be of Lower Greensand age. A quotation may make this more clear. He says:—"True Gault is to be seen near Punfield, in Swanage Bay, where it is underlain by a considerable thickness of Lower Greensand. It is traceable as Gault along the coast-line as far westward as Mewps Bay. At Lulworth Cove it is to be seen no longer as Gault, which in its argillaceous condition has either thinned out or given place to dark greenish sandy strata with zones of large concretionary nodules.

"These beds contain Gault fossils in abundance, and (what is well worthy of notice) pass upwards insensibly into Upper Greensand, and downwards into ferruginous sands of Lower Greensand.

"In the altered condition of the Gault, as present at Lulworth, one finds, therefore, an approach already to the condition of the so-called Gault as seen at Black Ven. And there is no doubt whatever that Gault in such condition is present both at Black Ven and in the sections to the westward. But is this all? I think it possible that Lower Greensand, which, as we have seen at Lulworth, actually accompanies the Gault to its extinction as a clay-bed, may form a part also of the still doubtful strata to the westward. As to the correctness of this supposition, it is only fair to say that I have no evidence whatever"*.

I have reason to know that in 1879 Mr. Meyer's opinion remained unshaken; for he says then "I still believe the Blackdown Greensand to represent a littoral deposit of more than one age or period, ranging possibly from the highest beds of the Lower Greensand to the lower beds of the Upper Greensand inclusive"†.

Not having myself as yet had an opportunity of visiting the Lulworth section, I have no opinion to offer. I can only remark that it appears to me that Meyer and Barrois (to whose views we shall next come) seem to differ in a rather important point in their de-

* Meyer, Quart. Journ. Geol. Soc. 1874, p. 382.

† Extract from a letter, by permission of the writer.

scription of this Lulworth section. As quoted above, Meyer tells us that "at Lulworth cove it [the clay-bed] is to be seen no longer as Gault, which in its argillaceous condition has either thinned out or" &c. Barrois, on the other hand, after describing all the beds at Lulworth except the base, adds "Sous ces couches se trouve une argile noire sableuse"*. This "argile noire" he apparently identifies with the Gault.

It may be partly for this reason that Barrois (1875) so positively asserts the position of the Blackdown beds as "*the lower part of the Upper Greensand.*" He lays down his definition of Upper Greensand very clearly as being the sum of the Warminster and Blackdown beds; so that according to him the term "Upper Greensand" $= \left\{ \begin{array}{l} \text{2. Warminster beds,} \\ \text{1. Blackdown beds.} \end{array} \right.$ "L' Upper Greensand n'est autre chose que la réunion de ces deux divisions." He finds both of them at Lulworth *above the black sandy clay*; and he identifies the Lower of these with the Blackdown beds on the ground that, out of 66 fossils which he had found there, 36 were characteristic of Blackdown.

The fact, however, that a black sandy clay or loam is locally found beneath the equivalents of the Blackdown beds (a fact attested by other writers in regard to some other localities †) will not of itself prove that black loam or clay is gault, nor warrant us in drawing a hard and fast time-line at the top of such a bed. For my own part I was hardly prepared to see Barrois' stratigraphical dictum on this point, after reading his own words in the earlier part of the paper, "on ne voit pas de relations stratigraphiques dans les Blackdown hills." It would not have struck me that either stratigraphical evidence or the proportion of fossils identified (very little more than half) warrant such a very positive inference.

Price (1879), after quoting the opinion of Mr. de Rance to the effect that the whetstones of Blackdown were the representatives of the "cowstones" of Dorset, "in which case the Blackdown beds might be the equivalents in time of the Upper Gault," adds, "The Blackdown beds, according to evidence furnished by the published list of fossils, and from those I have seen, appear to present a mixture of Upper and Lower Gault forms, leading to a supposition that these series of beds represent both divisions of the Gault."

By way of comment upon this, I would only add that if, as I imagine, Mr. Price includes among "the published list of fossils" all that have been referred in local museums to Blackdown, he may, and I think has, included some ‡ whose claim to a place on the list is more than doubtful.

To review the whole, it is clear that the present balance of opinion tends to the view that the Gault, or most of it, is represented in the Blackdown beds, while there is no necessary reason for limiting their age upward or downward to that of the Gault alone.

* Page 7.
† Mr. Horace Woodward, 'Geology of England and Wales,' p. 237.
‡ E. g. *Amm. falcatus.*

Correlation of the Blackdown Beds with other Localities.

Mr. Meyer, referring to Mr. Ralph Tate's description of the Cretaceous rocks of the North-east of Ireland (Quart. Journ. Geol. Soc. vol. xxi. p. 15), says that of the three zones of Tate "the lowest, or '*Glauconitic sands*' . . . apparently represents to some extent" his "beds 1 to 3 of the Devon sections," *i. e.* 1 to 3 of Meyer.

Prof. Duncan, referring to the coral fauna, which occurs high up in the series, and which is chiefly found at Haldon, and is but barely represented at Blackdown, says of this zone, that "the fauna is a poor representation of that of Gosau; but the facies is the same."

MM. Briart et Cornet have no hesitation in asserting the identity of the Blackdown beds with the Meule de Bracquegnies. The argument is based on the proportion of fossil species common to the two localities. Out of 93 species referred by them in 1870 to the Meule, 42 are found at Blackdown, 3 only in the English Gault, while 8, 13, and 5 respectively are found at Rouen, Sarthe, and in the Tourtia of Tournai and Montignies-sur-Roc, leaving a remainder of 22 not compared.

In the Geological Magazine, 1881, p. 431, I read that MM. Briart et Cornet had at that date raised the number of species from the Meule to 120. How far this may affect the proportion of fossils common to Blackdown I do not know; but taking their original comparison, we have 42 out of 93 species common to the two localities—that is to say, less than half. I should scarcely have thought that this fact alone would warrant the conclusion, "ces résultats ne peuvent laisser aucun doute sur l'identité de la meule avec les couches si remarquables de Blackdown."

Mr. Meyer, writing in reference to this subject in 1879, says:—"The fossils of the Meule de Bracquegnies, so many of which are referred by MM. Briart et Cornet to Blackdown species, differ in such points as bring them nearer to the Chloritic-Marl fauna; and they are, moreover, associated with Chloritic-Marl species; and for this reason I fancy our Blackdown fossils are older than their supposed Belgian equivalents"*.

To this I would add that the very small number in common with the English Gault (3 only) is remarkable, seeing that the Blackdown fauna has been supposed to contain a very large proportion of Gault forms†.

I observe also that the beds above the Meule, five in number, which separate it from the Chalk, are, according to MM. Briart et Cornet's section, all marly, and that bed J immediately above the Meule contains *Pecten asper*, which apparently does not occur in the Meule itself‡.

I am not aware that a detailed comparison of the Blackdown beds

* Extract from letter, by permission.

† Mr. J. S. Gardner tells me that the species supposed to be common to the two localities are very often not strictly identical.

‡ Plate i., Mém. Cour. tom. 34.

with those of Haldon has yet been made; and to do this is one of the main objects of the present paper.

Comparison of Blackdown with Haldon.

The beds at Blackdown have been in part, but only in part, described by Fitton; for his description refers almost entirely to the beds quarried for whetstones, which beds are less than a third of the whole supra-triassic series. I do not know of any detailed description of Haldon; but in the comparison of Blackdown and Haldon beds, which I shall presently give, I have been very much assisted, as regards the Haldon area, by the previous though unpublished observations of Mr. Vicary of Exeter.

In the days of Dr. Fitton pits were being worked at Blackdown almost continuously for a mile and a half, and at intervals still further. At the present date three only are being worked on the eastern side of the ridge, and all have been closed on the western escarpment. Some few of the lattter, however, have been open since my residence in the neighbourhood. These pits, with the help of cart-tracks and road-sections and frequent conversations with workmen, have given me, I think, a fairly clear idea of the structure of the hill.

In determining the zones of fossils at Blackdown I have been guided by:—

1. Seeing them *in situ*, or breaking up at leisure rock-matter brought to my house from a known bed;

2. Lithological characters of the matrix;

3. Comparison of information independently given by different workmen.

At Haldon I have been guided by:—

1. Seeing the fossils *in situ*;
2. Information given by Mr. Vicary.

I begin at the bottom of the series, and proceed in ascending order.

Bed 1. At the base of Blackdown is found about 30 feet of whity-brown sand rock, perfectly homogeneous throughout, with no trace of fossils*, so far as I am aware, and no sign of current-bedding. The workmen call it "white rock."

Bed 2. "Soft fine vein"=bed 8 of Fitton, a thin layer of concretions, generally only a few inches in thickness, used for scythe-stones.

Bed 3=bed 7 of Fitton, and called by him "Rock-sand." I find that the workmen now call it "Bottom-rock." It is about 4 feet in thickness, and of darker colour than the sand rock of bed 1 beneath it. There are very few fossils; but perhaps *Trigonia aliformis* is the prevalent one.

Bed 4=bed 6 of Fitton. "Bottom stones." Concretions used for whetstones, varying (as Fitton says) from a few inches to about 5 feet. *T. aliformis*, *Pectunculus umbonatus*, *Inoceramus sulcatus*.

Bed 5. "Burrows," concretions somewhat coarser than the last,

* Mr. Meyer tells me that he has found a very few in this bed.

used sometimes for whetstones, but chiefly for building. If we include the sand layers which divide the concretionary beds with the concretions themselves we may estimate it at about 4 feet. There are but few fossils, chiefly *Inoceramus sulcatus* and *Trigonia aliformis*.

Bed 6, = bed 4 of Fitton, is known as "Gutters." It consists of sand and concretionary layers, is about 5 feet in thickness, and contains but few fossils, but among them *Inoceramus sulcatus* and *Pectunculus umbonatus*.

Bed 7. A very fossiliferous band in sand. *P. umbonatus* is the prevailing fossil; but there are many others. These are found, to use the expression of the workmen, in "clumps;" that is to say, in clusters or colonies, with valves almost always attached, and with species but little mixed. They have evidently been deposited in still water, and are apparently in the habitat in which they lived and died. *Murex calcar*, with its long slender spines, is often found perfect at this zone.

Bed 8. This is also very fossiliferous, and the conditions are the same as those just mentioned. The prevailing fossil is *Turritella granulata* in "clumps." The individuals of this long univalve are inclined at all angles toward all points of the compass. Sometimes the "clumps" consist wholly or mainly of *Turritellæ*. Sometimes again, they are mixed with *Dimorphosoma* (*Aporrhais*) *calcarata* and *D. neglecta*; *Siphonia pyriformis* seems to be peculiar to this bed. This and the preceding bed run more or less into each other, but the order is generally as here indicated. Together the two beds constitute Bed 3 of Fitton, and are conjointly about 4 feet in thickness.

Bed 9. "Hard fine vein" = Fitton's bed 2. It is a thin layer of concretions used for scythestones.

Bed 10. "Red rock" = Fitton's bed 1. It is a very fossiliferous stratified sandstone in layers divided by sand; Bivalves in this bed have their valves nearly always separated, and species are completely mixed. There is some, but not much, indication of attrition, and some of the fossils are broken, while all lie flatly on planes of bedding. The sandstone is vertically divided at intervals of 1 to 3 feet by miniature joints, cutting clean through hard chalcedonic fossils, without leaving, as a rule, a single projecting splinter. Some of the fossils have their surface a little decomposed*, thus obliterating the finer striæ, and hence perhaps giving origin to the distinction between *Cucullæa fibrosa* and *C. glabra*, both of which occur in this bed. The prevailing fossil is *Cyprina cuneata*. *Exogyra conica* is also very common. *Trigonia scabricola*, though not so common, is confined mainly, if not entirely, to this bed. With this bed or some part of it the Haldon series probably begins, while with the bed beneath it the "whetstone beds" end. Thickness about 3 feet. I had a cartload of rock from this bed 10 brought to my house, and broke it up at leisure, and found the following approximate percentages:—

* *i. e.* have a pulverulent coating in the rock, which rubs off with a touch.

Cyprina cuneata	25
Exogyra conica	20
Cucullæa carinata	15
Cardium Hillanum	7
Venus sublævis, Cytherea plana, and allied forms	12
Cyprina angulata, C. rostrata	5
Turritella granulata	3
Cucullæa fibrosa (glabra)	3
Trigonia scabricola	3
Thetis gigantea	3
Other fossils	4
	100

I found in all 46 species in this bed, many of which range downwards into lower beds, while very few of them have a higher range.

Bed 11. A bed of variegated fine sand with thin lenticular and impersistent shell-bands. The fossils from these bands are mostly broken, and all much waterworn. *Pectunculus sublævis* and *Trigonia affinis* * abound, together with a few other species less abundant. It is about 18 feet thick, but the shell-bands are only about 2 inches in thickness.

Bed 12. Here there is not the slightest doubt about the agreement between Blackdown and Haldon. Beds 10 and 11 would appear to have some meagre representation at Haldon, to judge by the fossils which have come from the base of that series and by their mode of occurrence in it; though I must admit that I have not myself seen any thing there *in situ* which I could positively identify with either of them. But the greater part of the Haldon rock may be without hesitation referred to this bed 12, which therefore develops a greater thickness at Haldon than at Blackdown. At Blackdown it is about 25 feet thick, and consists of sand with layers of cherty sandstone passing upwards into chert. The characteristic fossil is above all others *Pecten quadricostatus*, which is never found lower down in the series. *Trigonia dædalea*†, *Pectunculus sublævis*, and *Exogyra*, mostly broken, are also found here, and a few others; but fossils, as a rule, are scarce. The Haldon bed, which corresponds with it, is probably about 35 feet thick, and this also consists of sand with several layers of cherty sandstone. Fragments of *Pecten quadricostatus* and of *Exogyra* are abundant in it at Haldon; but I could find hardly any thing else there. Both at Blackdown and at Haldon fossils of this horizon are commonly covered with concentric incrustations of chalcedony, exactly like those on the Triassic beekites at Paignton. On the Exeter road, near the Grand Stand at Great Haldon racecourse, I put my hand into a rabbit-burrow, about 3 feet above the junction with Trias, and brought out fragments of *P. quadricostatus* and *Exogyra*. It is thus evident that there at least

* Under this name I here include *T. læviuscula* and allied forms, which are all associated together in this one bed, and are found nowhere else. Mr. D'Urban, of Exeter, points out to me that Dr. Lycett, in his "Corrigenda" at the end of his Monograph, substitutes the specific name "*affinis*" for that of "*excentrica*" used in the text.

† Since this paper was read, I have found one which apparently came from a lower bed.

beds of this character extend very nearly down to the base of the series, while at Blackdown they only occur at the top, immediately beneath the chert gravel.

Bed 13. As a bed this can only be identified at Haldon, where it is found in many places. It is the "littoral concrete" of Prof. Duncan, celebrated for its coral fauna. In a sand-pit at the roadside on the east of Great Haldon, on the Exeter and Newton road, it may be described as consisting of three bands of fossil shells (for the most part broken) in a basis of sand. The two higher bands are thin and insignificant, but the third or lowest is about 1½ foot thick, a hard jaspideous mass full of fossil fragments. I detected in it *Ostrea* and *Exogyra* in abundance, *Trigonia Vicaryana*, Lycett, and *Vermicularia*, but no corals. I visited the place twice, the second time with Mr. Champernowne, but neither of us succeeded in finding a coral. Judging by the list of coral species, and by the specimens exhibited by dealers, one is apt to be much misled as to the character of this bed, and to suppose that it consists largely of corals and Polyzoa. The truth is that tons of the material might have to be removed before a nest of corals or Polyzoa would be found; and for a chance comer to find even a single specimen would be a fortunate circumstance. No such *bed* exists at Blackdown; but a very few specimens of the characteristic fauna have been found. The Blackdown specimens may be numbered on the fingers. Two or three specimens of *Trochosmilia* or *Smilotrochus*, one of (?) *Isastræa*, and one or two corals unnamed complete the list, so far as Blackdown is concerned, whereas a large and increasing list is referred to Haldon by Prof. Duncan, who, as already observed, compares the fauna to that of Gosau.

Bed 14. At Haldon, above the "littoral concrete," is found about 8 feet of schorlaceous and non-glauconitic sand. All the sand below this is more or less glauconitic. It contains a few fragments of *Exogyra*.

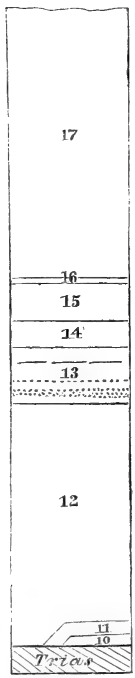
Bed 15. *Orbitolina*-chert, in layers 6 feet, is seen at Smallacombe Goyle, Little Haldon; but it seems to occur only locally. It is a glassy translucent chert weathering to a dull whitish surface; it is hard and brittle in the centre, but soft and earthy on the weathered exterior, and abounds in *O. concava*, Lam., and *Lima semisulcata*, Sow.

Bed 16. Chert gravel. At Blackdown this frequently caps the hill. It is found in a clayey matrix intermixed generally with very vesicular concretions of limonite. The latter has often been mistaken for iron slag, which it very much resembles in appearance. But as it can be seen not only lying round the old and present chert-pits, but also *in situ* in precisely the same condition, the tales of prehistoric bloomeries founded upon this evidence rest upon a very questionable foundation.

Bed 17. Flint gravel. None is found at Blackdown, I believe, to the north of Kentisbeare, but south of that place it generally caps the chert gravel without being mixed with it. At Blackdown probably it never much exceeds 10 feet, while it attains a thickness of 30 feet or 40 feet at Haldon. The springs which at Blackdown

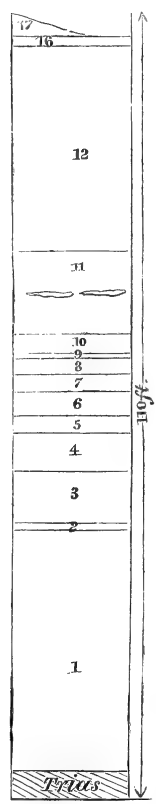
Fig. 1.—*Comparative general Sections at Haldon and Blackdown.*

Haldon.



17. Flint gravel.
16. Chert gravel.
15. *Orbitolina*-chert in beds.
14. Schorlaceous sand.
13. Haldon coral-zone.
12. Sand, with *Pecten quadricostatus* and cherty bands.
11. Sand, with *Pectunculus umbonatus* and *Trigonia affinis.*
10. "Red rock."
9. "Hard fine vein."
8. "Clumps," with *Turritella granulata* &c.
7. "Clumps," with *Pectunculus umbonatus.*
6. "Gutters."
5. "Burrows."
4. "Bottom stones."
3. "Bottom rock."
2. "Soft fine vein."
1. "White rock."

Blackdown.



come out at or near the base of the greensand, at Haldon seem invariably to come out at the base of the flint gravel.

To sum this up, we have, if we go to the base of the section (bed 1), probably still- and fairly deep-water conditions exhibited, but at first no signs of life. The concretionary layers which after a while begin to appear are of course superinduced; but just where they now happen to come in scanty traces of molluscan life begin to appear, while sponge-spicules begin to be abundant. The conditions, then, seem to point either to elevation or to silting up, at any rate to shallower water and more abundant molluscan life. We come first upon occasional waifs and strays, and then upon whole colonies of species fossilized without disturbance in their original habitat. Still shallower conditions seem to follow, marked by current-action, by the mingling of species, by separation of valves, by attrition and fracture. Corals and Polyzoa then incrust the littoral débris. Then there is a missing paragraph or two† in the natural chapter, which other localities may perhaps supply. But the flint gravel remains, telling its double or, rather, triple tale of subsidence till deep-sea conditions again prevailed, and of subsequent upheaval and subaerial denudation.

The following lists of fossils are corrected from those published by me in 1880. Several from that list, including *Pecten asper*, Lam., are now rejected on the ground that they have been found to be calcareous, or otherwise, in mineralogical character, manifestly differing from Blackdown specimens. When able with certainty to do so, I have recorded the beds, or range of beds, from which they severally come. The initials refer to the museums and cabinets in which the specimens may be seen. Thus :—J = Jermyn Street, K = British Museum at Kensington, B = Bristol Museum, E = Exeter Museum, T = Taunton Museum, V = Mr. Vicary's Collection, CE = that of Mr. Caleb Evans, W = that of Mr. Walrond, of Dulford House, near Collumpton, C = Mr. Champernowne, M = that of Mr. Meyer, D = my own.

Blackdown Fossils.

(Those which have been found at Haldon also are marked with an asterisk.)

Plantæ.

A fern-like impression. V.
Wood, silicified and (frequently) bored by Teredo? Common.
*Sequoites Woodwardii (*Carruthers*). Journal of Botany, 1867, p. 27, pl. lix. figs. 11–16.

Spongidæ.

Siphonia pyriformis (*Goldf.*). Bed 8. Common.
Spicula distributed throughout the beds. These have been treated in detail by Mr. E. Parfitt and by Dr. Carter in the works above quoted. Bed 5 seems most rich in these spicula.

Actinozoa.

*? Isastræa. D.
*Smilotrochus Austeni (*E. & H.*). [? Trochosmilia]. T, C.
Coral. E.
Probably all are traces of Bed 13, which is more fully developed at Haldon.

† Perhaps it was a land area during the age of the Chloritic Marl &c.

Echinodermata.

I am much indebted to Mr. Percy Sladen for criticisms on my former list under this head, and for his determination of some specimens of Asteroidea kindly lent for the purpose by Mr. Bidgood, the Curator of the Taunton Museum; also to Prof. Duncan for his determination of an *Echinus*.

Comatula. J.
Antedon incurva (*Carpenter*). Q. J. G. S. vol. xxxvi. (Nov. 1880) p. 552, pl. 23. fig. 1.
Stellaster Comptoni (*Forbes*) [Goniaster]. J, T.
—— elegans (*Gray*) [Goniaster]. J, T†.
Salenia, new sp. J.
Echinobrissus Morrisii (*Forbes*). J.
Cardiaster Perizii (*Sism.*) [bisulcatus, *Gras*]. J.
Enallaster Greenovii (*Forbes*) [Hemipneustes]. J. D'Orb. Pal. Franç. Terr. Crét. t. vi. p. 183, pl. 849; Wright, Pal. Soc. Monog. Cret. Echin. p. 290, pl. 64. figs. 2, 3.
Echinospatangus Murchisonianus (*Mant.*). Hemiaster Murchisoniæ (*Forbes*). J, W, D. Pal. Soc. Monog. Cret. Echin. p. 281, pl. 60. fig. 1, pl. 64. fig. 1.
Hemipneustes. CE.
Echinoconus. CE.
Pygurus lampas (*De la Beche*). E.
? Glenotremites, plates of. V.

In addition to the above, there is in the Taunton Museum, among the fine collection lately presented to it by Captain Fox, a Starfish impression, which was sent with the rest to Mr. P. Sladen, but concerning which the latter was not able to say any thing positively at the time.

Annelida.

Serpula filiformis (*Sow.*). Common. Bed 10 and others.
—— antiquata (*Sow.*). B.
—— plexus (*Sow.*). J, B.
—— vermes, *Sow.* B.
—— tuba (*Sow.*). B.
—— carinella, *Sow.* B.
*Vermicularia concava (*Sow.*). Common.
—— radiata (*Sow.*). B, E.
—— umbonata (*Sow.*). B.
Vermilia ampullacea (*Sow.*). J, B.

Crustacea.

Pollicipes lævis, *Sow.* V, CE, M.

Polyzoa.

Heteropora dichotoma (*Blainv.*)? B.
—— cryptopora (*Goldf.*). B.
Ceriopora gracilis (*Goldf.*). B.
*Radiopora bulbosa (*d'Orb.*). D.

Brachiopoda.

Rhynchonella depressa (*Dav.*). W, CE.
*—— latissima (*Sow.*). B.
—— ? species. Woodwardian Museum.
Crania. M.

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† Mr. S. Sharp has recorded the remarkable fact that the genus *Stellaster* is unknown in all the series intermediate between the Inferior Oolite of Northampton and the Blackdown beds.

LAMELLIBRANCHIATA.

*Ostrea frons (*Park.*). J, B, D. Bed 12.
—— macroptera (*Sow.*). B.
—— ? sp. E. CE.
*Exogyra conica (*Sow.*). Common. Beds 7–12.
—— undata (*Sow.*). B, CE.
*—— plicata (*Lam.*). J, E.
Anomia ? CE.
Hinnites, sp. J.
*Pecten Milleri (*Sow.*). Bed 10. Common. Fitton, pl. xvii. fig. 19.
*—— quadricostatus, *Sow.* Common. Characteristic of bed 12, beneath which it is never found.
*—— quinquecostatus (*Sow.*). J, B, E.
—— Stutchburyanus (*Sow.*). B.
—— orbicularis (*Sow.*). B.
—— ? sp. B.
*Lima semisulcata (*Sow.*). Common. Beds 14–16.
—— morenna ? (*d'Orb.*). V.
Plicatula ? CE, M.
Avicula lanceolata (*Forbes*). CE, V.
—— pectinata, *Sow.* M.
—— Rauliniana, *d'Orb.* M.
*—— anomala (*Sow.*). J, B, V. CE. Fitton, pl. xvii. fig. 18.
*Gervillia anceps (*Desh.*). Common. Beds 4–10.
—— solenoides (*Def.*). J.
*—— rostrata (*Sow.*). Common. Fitton, pl. xvii. fig. 17.
Inoceramus concentricus (*Park*). Common. Beds 8–10.
—— sulcatus (*Park.*). Beds 4–10, but especially 5–6.
Pinna tetragona (*Sow.*). J, B, W, CE.
Mytilus striatocostatus (*d'Orb.*). J, CE.
*—— tridens (*Sow.*). Common. Fitton, pl. xvii. fig. 14. Bed 10.
—— prælongus (*Sow.*). B, CE. Fitton, pl. xvii. fig. 15.
—— inæquivalvis (*Sow.*). B. Fitton, pl. xvii. fig. 16.
Modiola æqualis (*Sow.*). J.
—— lygeriensis (? *Sow.*). J.
*—— reversa (*Sow.*). Fitton, pl. xvii. fig. 13.
Arca, sp. ? J.
*—— rotundata (*Sow.*). B. Fitton, pl. xvii. fig. 8. Probably, like the corals, a trace of bed 13.
Limopsis, sp. ? B, W.
*Cucullæa carinata = costellata (*Sow.*). Common. Beds 8–12, but especially 10.
*—— fibrosa (*Sow.*). }
*—— glabra (*Park.*). } If these are two species, they may be distinguished as their name suggests. The one is glabrous and the other fibrous; but, as Mr. Sowerby remarks (Min. Con. vol. iii. p. 9), "the smoothness of the surface may arise from wear." Bed 10, where, as already remarked, the glabrous characteristic may be easily accounted for.
—— formosa (*Sow.*). B. Fitton, pl. xvii. fig. 7.
*Pectunculus umbonatus (*Sow.*). Common. Bed 7, and occasionally beneath it.
*—— sublævis (*Sow.*)†. Beds 11 & 12.
—— sp. ? J.

† In their descriptions, MM. Briart et Cornet (p. 62) appear to have referred to *P. sublævis* the characteristics of *P. umbonatus* and *vice versâ*: *e. g.*, describing *P. sublævis*, the authors say:—"Cette coquille est très voisine, par sa forme générale et ses ornements, de la précédente [*P. umbonatus*]. Elle s'en distingue cependant par sa longueur plus grande, et par son épaisseur beaucoup moindre, et par son crochet moins proéminent. Elle a aussi la côté anal tronqué, mais d'une manière moins accusée" (Mém. Cour. tome xxxiv. 1870, p. 62).

Nucula antiquata (*Sow.*). Common. Beds 7–10. = apiculata.
—— impressa (*Sow.*). Common.
*—— obtusa (*Sow.*). Common. Beds 7–10. Fitton, pl. xvii. fig. 11.
—— angulata (*Sow.*). CE, M.
*Leda lineata (*Sow.*) = Nucula lineata. Common. Bed 10.
Trigonia aliformis (*Park.*). Beds 4–6.
*—— scabricola (*Lycett*). Common. Bed 10.
*—— dædalea (*Park.*). Rare at Blackdown, but more frequently found at Haldon. E, D. Bed 12.
*—— affinis (*Sow.*). Bed 11. (Probably better known as "excentrica.")
*—— spectabilis (*Lycett*). Bed 10.
—— læviuscula (*Lycett*). V. Pal. Soc. t. xxii. fig. 6. Allied to T. affinis and found associated with it.
—— spinosa (*Park.*). Pal. Soc. vol. xxii., figured from Mr. Vicary's specimen. J, B, T, E, V, D. Beds 3–4.
—— sinuata (*Park.*). B, W Bed 12 probably.
Cardium Hillanum (*Sow.*). Common. Beds 4–12.
*—— proboscideum (*Sow.*). Bed 10.
—— subhillanum (*Leym.*). J, CE.
*Lucina orbicularis (*Sow.*). Common. Fitton, pl. xvi. fig. 13.
—— pisum (*Sow.*).
—— sp.? J.
*Cyprina angulata (*Flem.*). Common. Bed 10.
*—— cuneata (*Sow.*). Common. Bed 10.
—— rostrata (*Sow.*). Fitton, pl. xvii. fig. 1.
*Astarte formosa (*Sow.*). Common. Beds 7–10.
—— striata (*Sow.*). CE, J, B, V, D.
—— concinna (*Sow.*). B. Fitton, pl. xvi. fig. 15.
*—— obovata (*Sow.*). J, V.
—— impolita (*Sow.*). B, E. Fitton, pl. xvi. fig. 18.
—— cuneata (*Sow.*).
—— lineata (*Sow.*).
—— multistriata (*Sow.*).
Mentioned by Fitton, who figures the last (pl. xvi. fig. 17); but I cannot find them in any collection.
*Venus sublævis (*Sow.*). Common. Beds 10–12. Fitton, pl. xvii. fig. 5.
—— submersa (*Sow*). J, V. Fitton, pl. xvii. fig. 4.
—— faba (*Sow.*). B, V, CE.
—— immersa (*Sow.*). B, V, CE.
—— truncata = Cytherea truncata (*Sow.*). J, B, E, CE. Fitton, pl. xvii. fig. 3.
*Cytherea caperata (*Sow.*). Common. Beds 7–10.
*—— lineolata (*Sow.*). In most collections.
*—— plana (*Sow.*). Common. Bed 10.
—— subrotunda (*Sow.*). J, B.
—— (Venus) ovalis (*Sow.*). B, E.
Petricola? canaliculata (*Sow.*). Fitton, pl. xvi. fig. 11. B, M.
—— nuciformis (*Sow.*). Fitton, pl. xvi. fig. 10.
*Mactra angulata (*Sow.*). Common. Beds 7–10. Fitton, pl. xvi. fig. 9.
Amphidesma. B.
*Tellina inæqualis (*Sow.*). Common.
*—— striatula (*Sow.*). Common.
Psammobia gracilis (*Sow.*). CE, M.
—— sp.? J.? B.
Arcopagia Rauliniana (*d'Orb.*). M.
Lutraria? M.
Capsa elegans (*d'Orb.*). V.
Mya læviuscula (*Sow.*). B, V. Fitton, pl. xvi. fig. 6.
Goniomya. B.
*Corbula elegans (*Sow.*). Common.
—— truncata (*Sow.*). J, B, CE. Fitton, pl. xvi. fig. 8.
—— striatula (*Sow.*). CE, and Woodwardian Museum, Cambridge.
*Thetis gigantea (*Sow.*). Common. Bed 10.

Thetis Sowerbyi (*Röm.*). J.
—— major. } Thus distinguished by Sowerby (Min. Con.), who, however, con-
—— minor. } siders the distinction to be mainly one of size.
Myacites sp.? J, W, CE, D. Bed 10.
—— plicatus (*Sow.*).
—— ovalis (*Sow.*). B. Fitton, pl. xvi. fig. 5.

GASTEROPODA.

Murex calcar (*Sow.*). Common. Beds 7–10.
Pyrula depressa (*Sow.*). CE, B, W. Fitton, pl. xviii. fig 20.
—— sp.? J.
Fusus rigidus (*Sow.*). ? J, B, CE, V, T. Fitton, pl. xviii. fig. 16.
—— rusticus (*Sow.*). B. Fitton, pl. xviii. fig. 18.
—— quadratus (*Sow.*). B, V. Fitton, pl. xviii. fig. 17.
—— clathratus (*Sow.*). B, V.
—— ? sp. B.
Nassa costellata (*Sow.*). J, B, C, T, D. Fitton, pl. xviii. fig. 26. Bed 10.
—— lineata (*Sow.*). C, T, W, D. CE? Fitton, pl. xviii. fig. 25. Mr. Sollas has pointed out to me how closely this resembles the existing N. reticosa found off the Philippine Islands in 9 fathoms. Bed 10.
Cassidaria? CE.
*Natica gaultina (*d'Orb.*). Common. B. Beds 7–10. = N. canaliculata (*Sow.*).
—— granosa (*Sow.*). Fitton, pl. xviii. fig. 7.
—— sp.? W.
—— Dupinii? (*Leym.*). M.
—— Rauliniana? (*d'Orb.*). M.
—— excavata? (*Michelin*). M.
—— ervyna? (*d'Orb.*). M.
—— Geinitzii? (*d'Orb.*). M.
Fossarus carinatus = Natica carinata (*Sow.*). B, T. Fitton, pl. xviii. fig. 8.
Cerithium gracile = Littorina gracilis (*Sow.*). Fitton, pl. xviii. fig. 12. T, CE.
—— sp.? J, E, D, M.
Rostellaria tricostata (*d'Orb.*). M.
Tessalolax retusa = Rostellaria retusa (*Sow.*). B. Fitton, pl. xvii. fig. 22.
*Aporrhais Parkinsoni (*Mant.*) = Rostellaria Parkinsoni (*Sow.*). Common at Blackdown. Fitton, pl. xviii. fig. 24. Bed 10.
Dimorphosoma calcarata = Aporrhais calcarata (*Sow.*). Very common at Blackdown. Bed 8 especially, but found up to 10.
—— neglecta (*Tate*). Common. Fig. in Geol. Mag. 1875, pl. xii. fig. 13–15. Bed 8 especially; found up to 10.
Pterocella macrostoma (*Sow.*). = Rostellaria m. B. Fitton, pl. xviii. fig. 23.

The five preceding are given as described by Mr. J. S. Gardner in the Geol. Mag., 1880, who suggests that *D. calcarata* might be the male, and *D. neglecta* the female. In bed 8 they are found associated together, and where *D. calcarata* is doubtless the commoner form of the two.

*Turritella granulata (*Sow.*). Very common, especially in bed 8, which is its downward limit. It occurs also above bed 8 in lesser numbers; and there is a notable percentage of it in bed 10. I have not found it above bed 10.
—— costata (*Sow.*). B, CE.
—— angulata (*d'Orb.*).
—— subalternans (*Briart et Cornet*), pl. iii. f. 45. M.
—— sp.? CE, D.
Scalaria Fittoni (*J. S. Gardner*). J, K, B. Geol. Mag. 1876, pl. iii. figs. 10–11.
—— climatospira (*J. S. Gardner*). K, B. Geol. Mag. pl. iii. fig. 13.
—— pulchra (*Sow.*). B. Geol. Mag. 1876, pl. iii. fig. 14.
—— Dupiniana (*d'Orb.*). J, K, V. Geol. Mag. 1876, pl. iii. fig. 15.
—— Queenii (*J. S. Gardner*). Geol. Mag. 1876, pl. iii. figs. 1–3.
—— sp.? V, CE, D.

Disocheta Meÿeri (*J. S. Gardner*). Geol. Mag, 1880, pl. iii. fig. 5.
Pyrgiscus Woodwardii. Geol. Mag. 1876, pl. iii. fig. 19. K.
Littorina gracilis (*Sow.*). J, B, V. Fitton, pl. xviii. fig. 5.
—— conica (*Sow.*). B, CE. ? Phasianella.
—— monilifera (*Sow.*). J, E, V, E, CE.
—— rotundata (*Sow.*). B, CE. ? Phasianella.
—— pungens (*Sow.*). J, B, W, D, CE. Fitton, pl. xviii. fig. 5. ? Phasianella.
Phasianella striata (*Sow.*). B, W, D. Fitton, pl. xviii. fig. 15.
—— pusilla (*Sow.*). CE.
*—— sp. ? J, E.
—— formosa. B. Fitton, pl. xviii. fig. 14.
Dentalium cylindricum (*Sow.*). J.
*—— medium (*Sow.*). J, B, V, CE.
Entalis Meÿeri (*J. S. Gardner*). Q. J. G. S., Feb. 1878, pl. iii. fig. 40.
Pileopsis Seeleyana (*J. S. Gardner*). Q. J. G. S., May 1877, pl. vii. figs. 5–7.
*Actæon affinis (*Sow.*). Common. Beds 7–10.
*Avellana incrassata (*Mant.*)=Ringicula incrassata (*Sow.*). Common. Beds 7–10.

CEPHALOPODA.

Nautilus. 2 species. E, V, W, T.
Ammonites Beudantii (*Brongn.*). J.
—— Goodhallii (*Sow.*). Common.
—— varicosus (*Sow.*). Common.
—— lautus (*Sow.*). E.
—— splendens (*Sow.*). B, T, V, W, D, CE.
—— interruptus (*d'Orb.*). D.
—— serratus (*Park.*). E.
—— auritus (*Sow.*). B.
—— denarius (*Sow.*). B, T, V, W.
—— tuberculatus (*Sow.*). B, W, E.
Toxoceras Emericianus (*d'Orb.*), =Hamites spinulosus (*Sow.*). B, V, E.

The Ammonites at Blackdown seem to have been found mostly in the lower concretionary beds; but I have found one or two individuals of *A. varicosus* in bed 10. Mr. Vicary has *one* undeterminable *fragment* of an Ammonite from Haldon. It is the only instance of an Ammonite or, indeed, of any Cephalopod from Haldon that I can hear of.

An analysis of the above list teaches us that the Blackdown fauna (omitting the few corals) amounts to 196 species, and that 50 of these occur at Haldon also.

Of these 50 fossils in common, 1 is a plant, 1 is an Annelid, 1 is a Brachiopod, 38 are Lamellibranchiata, 8 are Gasteropoda, and 1 (a single individual) is a Cephalopod.

We find also that in every instance in which the Haldon fauna agrees with that of Blackdown, bed 10 seems to be the probable downward limit. It is significant that *Siphonia pyriformis*, *Inoceramus sulcatus*, and *Trigonia aliformis* are all apparently absent at Haldon; while we might almost say the same thing of *Pectunculus umbonatus* and of Ammonites generally†. This *negative* evidence is further confirmed by the absence of concretions suitable for making whetstones.

Positive evidence points in the same direction; *Pecten quadricos-*

† Mr. Vicary has 2 specimens of the former and 1 fragment of the latter.

tatus and *Trigonia dædalea* occur down to the very base of the series at Haldon; and the agreement is further confirmed lithologically by the chert-bands and the fragments of fossils covered with concentric rings of chalcedony. I think that beds 10 and 11 of Blackdown must be represented at Haldon, though I failed to identify them *in situ*. Some of Mr. Vicary's specimens exactly agree with bed 10 of Blackdown, both in the fossils and in their mode of occurrence. I infer therefore the presence of beds 10 and 11. Probably they are thin, and possibly only local; while the surface-slippage of bed 12 would quite account for the fact that they are not easily to be found*. The stream-sections also are greatly marked by débris, and the few clean-cut sections which exist exhibit generally only the upper portions of the series. The only complete section that I know of is that at Smallacombe Goyle, on Little Haldon, and this is partly a stream-section. These two distinct beds beneath bed 12 were seen by Mr. Champernowne and by myself; but we found no fossils in them.

Turning then, lastly, to the higher beds at Haldon, we find a thin band containing a distinct and all but unique fauna.

In this are several species of *Annelids*, but the main feature in the fauna is the *Corals*. Professor Duncan enumerates the following:—

Peplosmilia Austeni (*Ed. & H.*).
Placosmilia cuneiformis (*Ed. & H.*).
—— Parkinsoni (*Ed. & H.*).
—— magnifica (*Duncan*).
—— depressa (*E. de From.*).
Cyathophora monticularia (*d'Orb.*).
Favia minutissima (*Duncan*).
Trochosmilia varians (*Reuss*).
Thamnastræa belgica (*Ed. & H.*).

Haldonia Vicaryi, sp. nov. Stellaria incrustans, sp. nov. Baryhelia reticulata, sp. nov. Thamnastræa Ramsayi, sp. nov. Actinacis stellulata, sp. nov. —— insignis, sp. nov. Trochoseris constricta, sp. nov. —— Morrisi, sp. nov. Heliopora cærulea (*Grimm.*).	From Mr. Vicary's specimens. Q. J. G. S., Feb. 1879, pl. viii. figs. 1–18.

Smilotrochus Austeni (*E. & H.*) is also in Mr. Vicary's collection.

Speaking of *Heliopora cærulea* (Grimm.), Prof. Duncan remarks that this fossil from Haldon cannot be distinguished from the incrusting recent form.

Of *Polyzoa* there are many, but I am not aware that they are anywhere described.

Brachiopoda.—I have seen two species of *Rhynchonella* from this bed. One of Mr. Vicary's is labelled *R. Cuvieri*.

Of *Lamellibranchiata* there are several. Fragments of *Ostrea* and

* The terminal slippage of the higher beds over the lower ones is very general at Blackdown. The pits thus often traverse fossiliferous beds at the entrance, and afterwards pass under them.

Exogyra abound throughout the bed, and *Pecten quadricostatus* is found frequently. Mr. Vicary has also the following:—

Pecten? elongatus? Stuchburyanus.
—— ? striatocostatus.
Spondylus striatus (*Sow.*).
Lima? rapa.
Arca rotundata (*Sow.*).
Pectunculus umbonatus (*Sow.*).
—— ? sp. (very finely striated).
Trigonia Archiaciana (*Lycett*), Mon. Foss. Trig. Pal. Soc. pl. xxiii. fig. 7, =T. Vicaryana (*Lycett*).
Opis Galliennei (*d'Orb.*).
—— ? sp.
Radiolites?

A few unnamed Gasteropoda and one amphicœlian vertebra have also been found at Haldon, but possibly not from the bed of which we are now speaking.

Here then, if we omit the *Orbitolina* chert, the upward limit is reached, and nothing remains but the gravels. Barrois says, in special reference to the Isle of Wight Greensand, but perhaps in reference in some degree to equivalents elsewhere, "Le mélange d'espèces est dû à une confusion de couches." The stricture is, however, only in part applicable to Blackdown; for, though certain fairly marked zones may be traced, it would not appear, on comparison with lists of Cretaceous fossils from other localities *, that we have exclusively Upper Greensand fossils at the top, or exclusively Lower Greensand forms at the base, or, again, exclusively Gault forms in the middle.

It should also be remembered that beneath all the fossiliferous beds there lies bed 1, or 30 feet of whitish sand-rock, and that in regard to the age of this there is scarcely any thing organic to instruct us.

Discussion.

Mr. Champernowne corroborated the statement of the low position of *Pecten quadricostatus* at Haldon, and its high position in the Blackdown series. He was not sure, however, whether the Whetstone beds might not have a slightly greater thickness than Mr. Downes had given them. He called attention also to the interest of some of the specimens exhibited by the author. The paper was, he thought, a very valuable one.

Prof. Seeley thought that the materials brought forward by the author supplied the means of determining the parallelism of the Blackdown beds. In the Cretaceous series an association of fossils took place in following the beds westwards, similar to that which would be observed in the Tertiaries; the zones which were clear in the east, became confused in the west. He had formerly examined

* Catalogue of Cretaceous Fossils in the Museum of Practical Geology.

the district described by the author, and had come to the conclusion that, going westward, littoral conditions were found, and to this cause he attributed the changes in the fossils. He thought that the author's conclusions thoroughly confirmed Mr. Godwin-Austen's original hypothesis that the Blackdown series represented a littoral condition of the Gault sea, and showed that the Lower Cretaceous beds were derived from such crystalline rocks as exist to the west and south. If the Whetstone beds represent the Gault, we should not expect to find the same species as would occur in the deeper zone of water represented by the Gault clay, but a survival of Neocomian species mixed with widely spread forms characteristic of later deposits which are also sandy. The upper beds may well be Upper Greensand, and the absence of fossils is not conclusive that the bottom bed is not Lower Greensand. It may ultimately be possible to subdivide the beds still further by the evidence which the author presents.

Dr. Hinde called attention to the fact that some of the specimens on the table from Blackdown closely resembled certain beds at Haldon in being chiefly composed of sponge-spicules. They were thus largely of an organic character.

Mr. Meyer thought the information supplied by the author would enable us to correlate the beds. Beds 4, 5, 6, as containing *Inoceramus sulcatus* (which he had never obtained himself), would make these Middle or Upper Gault. He had obtained, many years ago, in the lowest beds, a *Rhynchonella* and a *Plicatula* resembling Lower Greensand forms. He was of opinion that the paper was very valuable.

Mr. Hudleston thought, from the general lie of the country, and the absence of palæontological evidence, it was not likely the lowest beds were Lower Greensand; for these had disappeared at the Vale of Wardour. The fact that *Inoceramus sulcatus* occurred in the lowest beds of the fossiliferous series at Blackdown indicated that these beds were the base of the Upper Gault; so the unfossiliferous sands might represent Lower Gault.

Prof. Judd said that, according to M. Barrois, the Folkestone beds belonged rather to the Gault than to the Neocomian.

Mr. Gardner said that he could not identify the Blackdown fossils with those of the Gault; they more resemble those of the Aix-la-Chapelle beds.

Mr. Tawney said that he regarded the *Amm.-mammillaris* bed as Gault, but the rest of the Folkestone series as Lower Greensand. He asked at what levels Ammonites were found in the Blackdown section, and what Ammonite was found at Haldon.

Mr. Whitaker asked if any of the fossils were derived, and if the author had compared the beds with those further east.

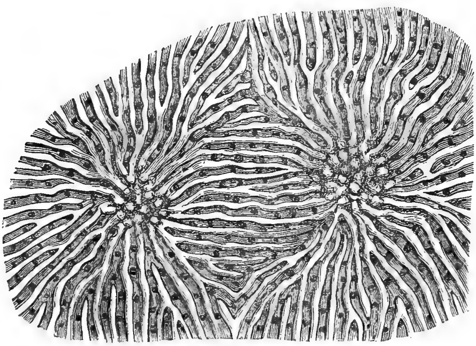
The President inquired if the nine beds spoken of in the Blackdown area were wholly wanting at Haldon. At Black-Ven, Lyme Regis, the Lower Greensand was visible below the Lower Gault. Prof. Renevier had endeavoured, some years ago, to correlate the Blackdown beds with the Gault proper without complete success.

Mr. Downes thought that the thickness beneath bed 12 at Haldon, mentioned by Mr. Champernowne, was exceptional. He gave some additional facts as to the sponge-spicule beds. The Haldon Ammonite was too fragmentary to be determined; he gave some details of those found at Blackdown. He had not visited the sections further eastward. In answer to Mr. Whitaker he said that there is no indication of redeposition in the lower beds, though in and above bed 10 it is quite possible and, in some instances, very probable. In those higher beds broken fossils are frequent, and current action often evident. The bottom bed at Haldon corresponded with about bed 12 at Blackdown.

7. *Description of a New Species of* Coral *from the* Middle Lias *of* Oxfordshire. By Robert F. Tomes, Esq., F.G.S. (Read June 22, 1881.)

Since the publication of my paper on the Fossil Corals of the Lias, published in the Society's Journal in 1878, only one new species has to my knowledge been obtained from the Middle Lias of this country, although an interesting series has been secured from the *Angulatus*-beds of the Lower Lias of Worcestershire. I refrain for the present from remarking upon the latter, but describe the Middle Lias species as follows:—

Fig. 1.—*Two Calices of* Thamnastræa (Synastræa) Walfordi, *Tomes.* (Three times nat. size.)



Thamnastræa (Synastræa) Walfordi, n. s.

The corallum has a rounded depressed form, and has the upper surface evenly and slightly convex. The outer margin is thin.

The calices are round, rather superficial, far apart, and irregularly placed, but with a tendency to a linear arrangement, either in straight lines or curves.

The septa and septal costæ are nearly straight, and have a distinctly radiate composition without any indication of a parallel arrangement of the costæ.

The union of the costæ with those of adjoining calices is usually at an angle, which is sometimes very distinct, and probably indicates the position of a rudimentary wall.

The septa and septal costæ are nearly of uniform thickness, many of them anastomose near to the columella, into which they pass. They are long, rather thin, and there is no indication of their being perforate or having a moniliform margin.

The columella is small and composed of papillæ.

The synapticulæ are rather numerous, distinct, and resemble those of typical Fungidæ.

The under surface of the corallum is hidden in the matrix, in which the specimen is partly imbedded.

Height of the corallum 1 inch.

Diameter of the corallum about 3 inches.

Distance of the calices from each other from 3 to 6 lines.

From the *Ammonites-spinatus* beds of the Middle Lias marlstone, Aston-le-Walls, Oxfordshire.

In the collection of Mr. E. A. Walford, to whom I am indebted for the use of the only specimen yet discovered.

Obs. This species appertains to the subgenus *Synastræa*, as defined by M. de Fromentel in his valuable Introduction to the Study of Fossil Corals. It is distinctly one of the Fungidæ, the synapticulæ being of a typical kind. In some of the *Thamnastrææ* the endotheca, though not by any means dessepimental, is nevertheless composed of synapticulæ which are not of a typical form. This is probably the reason why the *Thamnastrææ* were placed by MM. Edwards and Haime with the Astræidæ. M. de Fromentel, however, as long ago as in 1858–61, when his work above referred to was published, had clearly distinguished a species from the Corallian of Champlitte as appertaining to the Fungidæ, and spoke of it and other affined species in the following words: —

"Cette espèce montre d'une manière à peu près évidente, ce que déjà depuis longtemps nous avons remarqué, c'est que la plupart des *Thamnastrées* ont des synapticules et non traverses proprement dites, et qu'elles devraient faire partie de la famille des *Cyathosériniens*."

The present species, with one before described by me under the name of *Thamnastræa Etheridgei**, also from the Middle Lias of Oxfordshire, presents the same subgeneric characters which occur in *Thamnastræa arachnoides* from the Coral Rag of Steeple Ashton; and it is in some degree remarkable that the only species which have yet been met with in the English Lias should resemble the Coral-Rag rather than the Inferior-Oolite forms.

Discussion.

Prof. Duncan remarked on the interest of Mr. Tomes having found a compound coral in the Middle Lias, but he had a doubt whether the specimen was sufficiently well preserved to found a new species upon. He was inclined to think that it was very near to, if not identical with, the *Thamnastræa Walcotti*, Dunc., of the Inferior Oolite. He stated that to Reuss belonged the merit of removing the *Thamnastrææ* from the Astræidæ and placing them among the Fungidæ.

The President spoke of the high value of Mr. Tomes's work on the fossil Corals of Warwickshire. He agreed with Prof. Duncan as to the bad state of preservation of the specimen.

* Quart. Journ. Geol. Soc. 1878, vol. xxxiv. p. 190.

8. *Additional* NOTES *on the* LAND PLANTS *from the* PEN-Y-GLOG SLATE-QUARRY *near* CORWEN, NORTH WALES. By HENRY HICKS, Esq., M.D., F.G.S. (Read November 16, 1881.)

[PLATE III.]

IN my former paper, read before the Geological Society in May 1881, I mentioned that, in addition to the plant-remains from the Pen-y-glog grits and shales chiefly referred to in that paper, I had also obtained some evidence of a still earlier flora in the underlying slates. Since then I have revisited the slate-quarry; and with the kind assistance of Mr. Phillips, the manager of the quarry, I have secured specimens which prove beyond doubt that fragments of land-plants occur in tolerable abundance at several horizons to the very base of the quarry. In consequence of the slaty cleavage and the difficulty therefore of obtaining bedding-surfaces, large specimens can seldom be found. All the specimens are in a mineralized condition, the larger ones in the form of anthracite with a bright glassy fracture. The anthracite is very hard; and there is often a thickness of from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch remaining as the result of the decomposition of a fragment of the plant*.

The smaller stems and branches show little more than a carbonaceous film. A light fibrous mineral, a hydrated magnesian silicate, now spreads more or less over the surfaces of most of the specimens and fills up also the fractures. The anthracite, though so pure, appears here to have been the result of the slow decomposition of one plant, accompanied by pressure only. The conversion could not have been the result of heat, as there is no evidence in the rocks or the associated fossils of their having been subjected to a high temperature. This fact may, I think, throw some light on the way vegetable matter may, in many cases, have been converted into anthracite. I have shown most of the specimens to Mr. Carruthers; and he has kindly written me a note in which he says that "it is

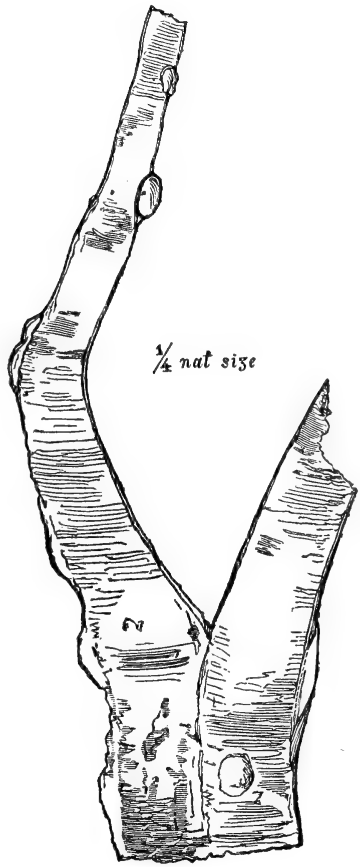
* Mr. T. Davies, F.G.S., has kindly examined the anthracite; and he says as follows:—

"Your coal is a true anthracite. Heated in a test-tube to a red heat it decrepitates slightly, but gives off no appreciable quantity of gas; nor does it seem to be affected in any way whatever by prolonging the heating. After four hours' subjection to a bright red heat, I obtained 0·5 per cent. of ash; as you will see, this is considerably below that given for some of the anthracites of Pennsylvania, though it is not improbable that some of the compact kinds of this (Penns.) coal, which are regarded as quite unfit for fuel, may contain as small a quantity. I recollect reading in the Comptes Rendus in 1867, a notice of some anthracite, analyzed by M. Daubrée, which contained the following:—

Carbon..................	97·6
Hydrogen	0·7
Oxygen..................	1·7
	100·0

You see here is no room left for ash."

Fig. 1.—*Portion of dichotomously branching Stem of* Berwynia Carruthersi, *Hicks.*



evident they were vascular plants; for not only do the larger specimens exhibit a large amount of carbon, but there is clear evidence in some of the specimens of the presence of a thick vascular axis in the stem and of a considerable cortical covering. In one specimen (Pl. III. fig. 2) there are indications of the passage of vascular bundles from the axis through the cortical layer as if to leaves, though there are no traces of the leaves themselves or of the scars which leaves would form on the stem. In addition to these characters, the dichotomous division of the stem points to a relation with the arborescent Lycopodiaceæ of the Devonian and Carbonife-

rous measures; but whether they represent a new generic type or an early form of *Lepidodendron*, cannot be determined."

From the specimens which have been already obtained, it is evident that the trees attained to a considerable size, many of the fragments being from 4 to 5 inches wide as now compressed on the slabs. In the quarry, before the larger blocks were broken up, I traced some branches to some feet in length. All, as far as could be made out, were fragments of the trees only, as if they had floated from some neighbouring land into their present position.

Though the majority of the specimens do not appear to retain indications of leaf-markings, some are wrinkled in a manner which, I think, proves that the plant was freely covered with leaves spirally arranged around the stem, as in *Lepidodendron*. In some of the decorticated fragments (see fig. 1, Pl. III.) these markings are still more definite. Perhaps the most interesting are some fragments, apparently of roots, having a close affinity with *Stigmaria* (see figs. 3, 3 *a*, Pl. III.). If these can be proved to belong to similar plants to the above-described stems and branches, we have here an interesting early type of plants combining the characters of *Sigillaria* and *Lepidodendron* in a more marked degree than any which appear hitherto to have been found. This would tend also to confirm the view, held for some time by Mr. Carruthers and others, that *Sigillaria* was allied to the Lycopodiaceæ. These specimens were found near the base of the quarry, in a bed which contained also some anthracitic fragments of stems; and it seemed to me that the evidence generally tended to show that both were fragments of different portions of the same or of similar kinds of plants. In these specimens a very thin film of carbonaceous matter only remains, as in the case of the younger branches. Over this surface are scattered, apparently with no definite order, numerous circular slightly raised scars. In their centre there is frequently to be seen a small raised point, probably the spot through which the vascular bundle passed (Pl. III. fig. 3 *a*). Though the scars seem to be scattered about irregularly, yet they appear more or less in groups; and possibly a somewhat regular arrangement could be observed but for the distortion produced by the cleavage. They number in some places as many as twenty or more to the square inch; and their average size may be said to be about $\frac{1}{16}$ of an inch in diameter. Between the scars the surface is more or less wrinkled; and on this surface are seen scattered about numerous slender tapering fragments, probably portions of rootlets (see fig. 3, Pl. III.).

I have not been able to find descriptions of any plants hitherto found to which this plant with the very marked combined characters above given could be very closely associated. The genera which approach nearest to it are *Cyclostigma*, *Arthrostigma*, and *Psilophyton*; but to neither of these does it seem to be very intimately allied. I am therefore tempted, considering the numerous specimens which have already been found, and the apparent abundance of these plants in the early Silurian rocks of North Wales, to

give a new generic name; and for this purpose *Berwynia*, after the Berwyn Hills, in which the Pen-y-glog quarry is situated, seems an appropriate one. I propose to call the species *Carruthersi*, after Mr. Carruthers, to whom I am indebted for much kind assistance in my endeavours to make out these early plant-remains.

It is possible that the spores referred to in my former paper, as occurring in considerable abundance in the overlying grits and shales, which Mr. Carruthers in his note mentioned as agreeing "with the forms of the microspores of Lycopodiaceæ, both recent and fossil," may also belong to the plant now described, as fragments of stems of a similar nature to those found in the slates occur also in some of the overlying beds in association with these spores.

The specimen (fig. 4, Pl. III.) which I found along with the plants in one of the bands of shale between the grits at the top of the quarry, resembles so strongly the fossil called *Parka decipiens*, found in the Old Red Sandstone in Scotland and elsewhere, that one is tempted to seek for some relationship between them. If, however, the latter are, as has been generally supposed of late years, the eggs of large Crustacea (*Pterygotus* &c.), this resemblance must be purely accidental, since all the evidence that I have been able to obtain at Pen-y-glog goes to prove that the specimens found there (and they are abundant in some of the beds) must be seed-vessels of some plant, and must, moreover, have drifted from some neighbouring land into their present position along with the other plant-remains. No Crustacea have as yet been found with them; and the large forms allied to *Pterygotus* have not been discovered anywhere in Wales, and probably not elsewhere in beds at so low a geological horizon. Moreover, in beds where other Crustacea (Trilobites &c.) occur in the greatest abundance these specimens are seldom if ever found. On the other hand, they are invariably accompanied by plant-remains in all the beds in which they have been discovered.

Description of genus and species:—

Berwynia Carruthersi, gen. and sp. n.

Apparently a Lycopodiaceous plant of large size. Stem thick, branching dichotomously (see fig. p. 98), surface slightly furrowed longitudinally, decorticated specimens showing interrupted markings more or less spirally arranged around the stem; branches long, and diminishing very gradually in their width. Root (probably of this plant) marked freely, but rather irregularly, with slightly raised rounded scars, having in their centre a small elevated point, probably the spot through which the vascular bundle passed. The scars are about $\frac{1}{16}$ of an inch in size, and average about 20 to the square inch of surface, the spaces between being slightly wrinkled. Rootlets slender and tapering.

EXPLANATION OF PLATE III.

Fig. 1. *Berwynia Carruthersi*: decorticated branch. Natural size.
2. —— ——: branch showing cortical layer, and probably at *a* the positions of some leaves. Nat. size.
3. —— —— (?): portion of root, showing scars and fragments of rootlets. Nat. size. 3 *a* & 3 *b*, scars and rootlets: × 2.
4. —— —— (?): fragment of a capsule containing numerous spore-like bodies. Nat. size. 4 *a*, spore-like bodies: × 8.

Discussion.

Mr. Carruthers complimented Dr. Hicks upon his persevering investigations of these unpromising rocks. Not much could be said about the materials. The carbon (in the condition of anthracite) of the plants was remarkably preserved, because the remains had been sealed up in clay; but it was in such a condition that not much could be determined as to the plants. The outward form, however, was to some extent preserved; and from indications, though obscure, he considered the remains not Algæ, like those formerly discovered by Dr. Hicks, but higher forms of dry-land vegetation belonging to the Lycopodiaceæ.

Dr. Sterry Hunt said he agreed with Mr. Carruthers as to the cause of these remains being anthracitic. He thought, as a rule, that conversion into anthracite was due not to heat but to circumstances of deposition. Where there was free passage for atmospheric water, anthracite was likely to result.

Prof. Rupert Jones said that Principal Dawson had called attention to the parts of the old jungles which had helped to make coal. Those portions of the fallen wood which had remained for a time exposed to the air had been converted into mineral charcoal.

Prof. Duncan doubted whether all the remains were of vegetable origin, and said that dichotomy did not prove the remains to be plants. He thought some of the markings might be merely mineral. Others, however, he thought were true plant-remains.

Mr. Carruthers, after pointing out that the metamorphic action which had converted the substance of the plant into anthracite would leave no tissue that could be distinguished, stated that his experience as to the remains of plants in the state of carbon occurring in arenaceous rocks differed from Dr. Sterry Hunt's; for he had never found that the carbon remained in these porous rocks. It was not so in the Carboniferous Sandstones of Scotland.

Dr. Woodward said plant-remains (*Glyptodendron*) had been found in America slightly lower than those of Dr. Hicks; so there was no improbability in the latter being plant-remains.

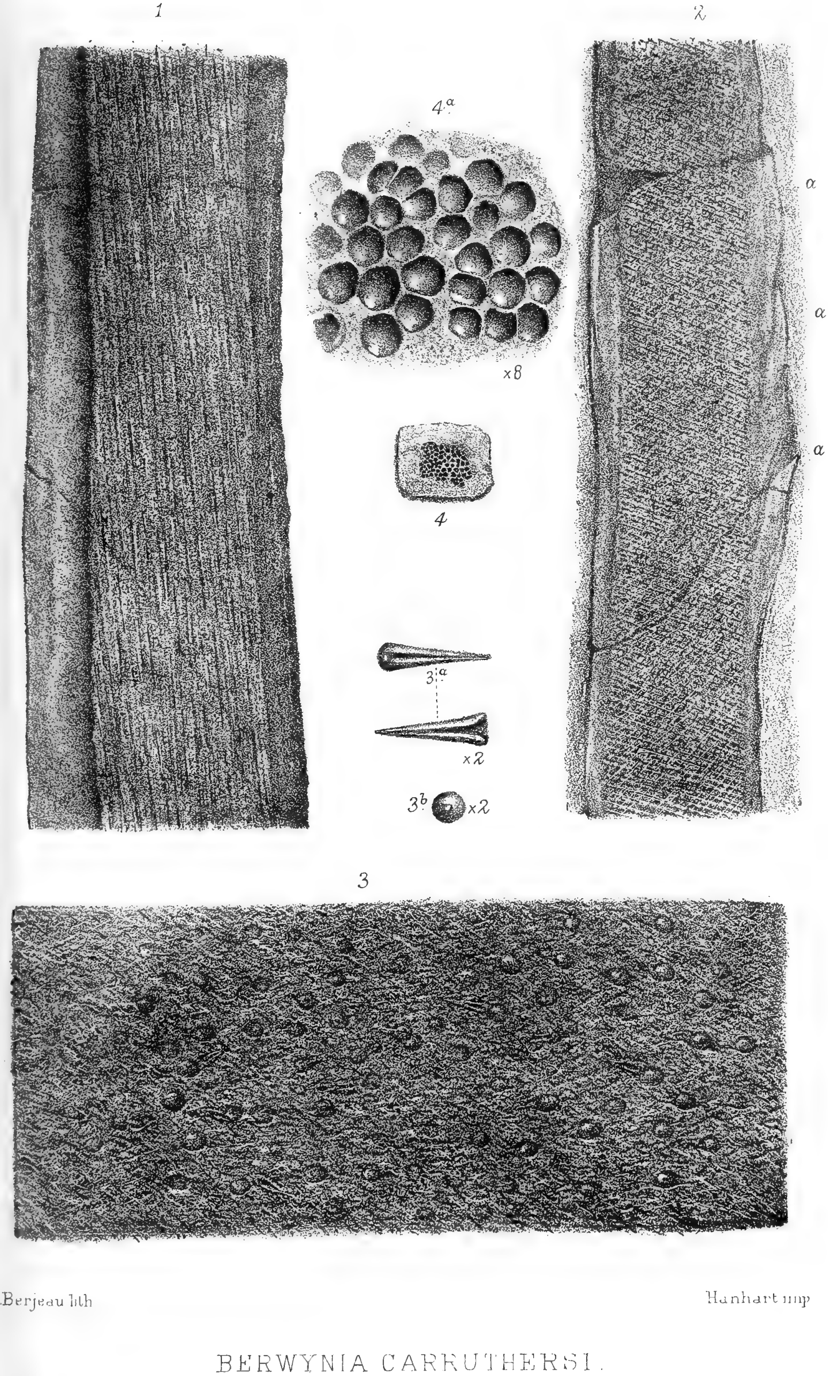
Mr. Tawney asked if there were not marks of Graptolites on the slabs, and how would these be associated with land-plants?

Prof. Morris thought some of the markings might not be con-

nected with the structure of the plants, but that possibly they were spores of some kind. The structure of the shale seemed interesting and should be further carefully examined. The plants of the Halifax Coal-measures were derived from the Ganister series, where they were associated with *Aviculopecten*, *Goniatites*, and other marine forms.

The PRESIDENT said that the cortical portions of *Sigillaria* in the sandstone of the Pennant measures were often converted into a substance resembling anthracite. Some of the specimens of Dr. Hicks could hardly be other than vegetable.

Dr. HICKS said he had referred in his previous paper to *Glypto-dendron*. It was as nearly as possible on the same horizon. The structure noticed by Prof. Duncan was natural to the anthracite. Plants were commonly found in these older beds associated with marine remains. He had referred to the fact that all the plant-remains were in a fragmentary condition, and that they must have drifted into their present positions.



C. Berjeau lith

Hanhart imp

BERWYNIA CARRUTHERSI.

9. Notes on Prototaxites and Pachytheca discovered by Dr. Hicks in the Denbighshire Grits of Corwen, N. Wales. By Principal Dawson, LL.D., F.R.S., &c., M'Gill College, Montreal. (Read November 16, 1881.)

Specimens of the first-mentioned fossil were kindly sent to me by Dr. Hicks, at my request, but unfortunately arrived when I was at my summer residence at Little Metis. Though without the means of examining them microscopically, I ventured to write, after studying them with a good pocket-lens, that they resembled *Prototaxites*, and could not be referred to Algæ. The latter conclusion might appear rash; but there are, to the practised eye, indications in specimens of this kind which can scarcely deceive. The fibrous and highly carbonaceous nature of the darker specimens, and the silky and incoherent texture of the lighter-coloured ones, are characters never found in any fossil plants except those having durable woody tissues. Further, the occurrence of the material in angular fragments and in a condition approaching to that of the mineral charcoal of the Coal-measures, proves subaerial decay, little likely to have occurred in the case of aquatic plants. From the state of preservation of the specimens, I also inferred that, if really of the nature of *Prototaxites*, they might throw some additional light on its structure, as the specimens previously studied had been from entire trunks in a silicified state.

On my return to town, I found awaiting me the Journal of the Geological Society containing Dr. Hicks's paper; and the figures there given showed at once the correctness of the reference made by Mr. Etheridge of the plant to *Prototaxites*, and its close resemblance to *P. Logani**, except in the appearance of bifurcating fibres, a character which I have not observed, and which may be merely an error in observation or in drawing.

Portions of the specimens sent by Dr. Hicks were at once prepared, not only by slicing but by treatment with boiling nitric acid, and by diffusion of the more lax fibres in water and in Canada balsam. On examination they gave the results stated below.

In state of preservation the two kinds of specimens examined are somewhat different. The dark variety has the long cells or woody fibres filled with rods of transparent siliceous matter, and the walls are represented by a thick structureless layer of carbon, which often shows angular cracks, such as appear in the walls of thick-walled woody fibres when carbonized. These cracks are sometimes transverse, giving a scalariform appearance, but they do not represent a true structure. The internal siliceous casts, when bared by nitric acid of their carbonaceous coating, show here and there transverse or spiral markings, produced by the projection of the ligneous lining on the inner side of the cells. There is no trace of

* Report on Devonian Plants of Canada, 1871, pl. ii.

the intercellular flocculent matter produced by decay of the outer surfaces of the cells or their connecting tissue, such as I have described in the silicified trunks of *Prototaxites*.

The lighter-coloured variety has probably been originally preserved in a similar manner; but the woody envelope of the fibres has been entirely removed, leaving only the siliceous internal casts, which are so lax that they can be scraped into water and viewed as transparent objects without slicing. This is precisely the state of the asbestos-like silicified Coniferous wood found in the gold gravels of California. These rod-like siliceous casts preserve on their surfaces distinct traces of the irregularly spiral ligneous lining of the perished cell-wall. A few of them also show rounded bodies of brownish colour in their interior. These may be ferruginous concretions, but are possibly granules of resinous matter, in which case such tubes may represent resin-cells.

In all the above particulars these specimens confirm my original determination of the woody character of *Prototaxites*, to which genus they undoubtedly belong. They differ, however, from *P. Logani* in the smaller diameter of the fibres, and in the ligneous lining, which presents the appearance of interrupted transverse bands rather than regular spirals. These characters would seem to indicate a distinct species, which may therefore be named *P. Hicksii*, in honour of its discoverer*. I may recall here a statement made in my report on the Devonian plants of Canada, that in 1870, when Mr. Etheridge was so kind as to permit me to examine the slabs in the Jermyn-Street Museum, with *Pachytheca* of Hooker from the Ludlow, I recognized, associated with this, fragments of wood having the structure of *Prototaxites*. The similar association in Dr. Hicks's specimens and the peculiar fibrous structure of the walls of *Pachytheca*, as figured by Mr. Etheridge, may well excite the suspicion that these bodies are connected with *Prototaxites*, especially as similar round bodies are seen in beds holding this fossil in Canada, though without distinct structure. In this connexion it is to be observed that the bodies in question are probably seeds rather than spore-cases, and that they have the structure of *Ætheotesta*, to which, in a recent paper in the Journal of the Geological Society†, I have referred a similar seed, found in the Devonian of Scotland.

With reference to the affinities of *Prototaxites*, I have not made the crude assertion attributed to me, that this plant "belonged to Taxineæ." I merely compared its structure to the lax spiral fibre of some Taxine trees, and especially to certain Taxine woods fossilized after long immersion in water, with which we are familiar in the Tertiary formations. This was all that was intended by the name *Prototaxites*, except to suggest that this plant was one of the prototypal gymnosperms of the Palæozoic period. Further, in consequence of its upper limit in Canada being apparently the Lower Devonian, where it comes into contact with the wood of the earliest species of *Dadoxylon*, I have conjectured that it would be found in much older

* Instead of *Nematophycus Hicksii*, as proposed by Mr. Etheridge.
† Vol. xxxvii. p. 306, pl. xii. fig. 14.

formations*, and am therefore not surprised to find this conjecture realized by the discovery of Dr. Hicks.

In the specimen sent to me there appears, besides the fragments of *Prototaxites* and a few rounded impressions probably of *Pachytheca*, a fragment of the rhizoma of *Psilophyton* and portions of epidermal tissue. The state of preservation of these bears additional testimony to the woody and durable texture of *Prototaxites*. Still further, in recent explorations in the Bay de Chaleur, I have found in the Lower Devonian silicified trunks of *Prototaxites* two feet and a half in diameter; and these lie in beds abounding in entire specimens of *Psilophyton*, some of them apparently in the place of their growth, and in a formation which contains only land plants, associated in some layers with remains of fishes and of bivalve Crustaceans, minute Gasteropods, and *Spirorbis*, the whole much resembling the coal-formation in its mineral character and grouping of fossils. The idea that *Prototaxites* may have affinities with Algæ has been sufficiently disposed of in my communication to the 'Monthly Microscopical Journal' in 1873; and the characters and state of preservation of Dr. Hicks's specimens fully confirm the reasoning in that paper. The large specimens recently obtained at the Bay de Chaleur also enable me to reaffirm the existence of a dense coaly bark at the surface of these trees. Some of them show on their weathered ends evidence of remarkably regular exogenous rings, extending from the surface nearly to the centre. There may, however, have been an internal axis or medulla, different from the outer structure; and this I hope to be able to ascertain by series of slices from the centre to the circumference of the trunk.

I have lately had a number of slices made of the large silicified trunks found last summer near Campbellton, New Brunswick. They present appearances of a very peculiar and interesting character. In the better-preserved specimens the large cylindrical fibres are filled with rows of rounded concretions of silica, often enclosing limpid hexagonal crystals. In many cases they present the most deceptive resemblance to the bordered pores of coniferous wood, and in other modes of occurrence might be mistaken for spores of some parasitic fungus. Under polarized light, however, they are seen to be merely crystalline and concretionary; and when the fibres show their true structure, this is reticulated or spiral, as in the ordinary specimens of *Prototaxites*. In many parts of these specimens, however, the formation of granular crystals of quartz has completely disorganized the structure. I have referred to concretionary appearances of the kind above described, in my "Report on the Devonian Plants of Canada," as occurring in the Gaspé specimens of *Prototaxites*; but they are coarser and less beautiful than in those from Campbellton.

It is possible that these appearances may throw some light on the globular bodies observed in the cells of the Welsh specimens of *Prototaxites* and *Pachytheca*, though I cannot certainly affirm that the latter are concretionary and not structural.

* Report on Devonian Plants.

I have sent a fragment of the Campbellton *Prototaxites* to Mr. Carruthers, and have no doubt that, if sliced, it will show the peculiar state of mineralization above described.

Mr. Hicks having been so kind as to send me a specimen of the *Pachytheca* from Corwen, I have compared it with Mr. Etheridge's figures and description, and with similar objects from this country and elsewhere. Mr. Etheridge's figures very accurately represent the specimen examined by me; but I would make the following additional remarks. The specimen is globular, but slightly flattened in the plane of the bed. It is three millimetres in diameter, and consists of an internal globular nucleus of granular texture, rather more than one millimetre in diameter, surrounded by a thick testa or outer envelope of radiating fibres. The fibrous part is in the same state of preservation as one of the kinds of associated fossil wood, the walls of the fibres being carbonized and the cavities filled with transparent silica. Under high powers the "spore-like bodies" referred to by Mr. Etheridge resolve themselves into alternate swellings and contractions of the cavities of certain of the fibres, others presenting a more uniform cylindrical form. The latter occasionally show the irregular transverse bands observed in the wood of *Prototaxites* from the same locality. The internal nucleus is apparently wholly granular, as if it had been composed of parenchymatous tissue.

There are in my cabinet specimens of similar bodies in a pyritized state, from the Upper Silurian (Lower Helderberg) of Cape Bon Ami, in New Brunswick, where they are found associated with fragments of wood of *Prototaxites.* Though on the whole less perfectly preserved, as to structure, than the Welsh specimens, when sliced in certain directions they present traces of a micropyle and embryo, and are, in my judgment, true seeds.

There seems little doubt that these New Brunswick specimens and those from Corwen may be referred to Brongniart's genus *Ætheotesta*, and that they are nearly allied to my *Ætheotesta devonica* from the Devonian of Scotland (discovered by Rev. Thomas Brown, of Edinburgh). In connexion with the structures observed in the Corwen specimens, it is worthy of note that Brongniart says of his species *Æ. subglobosa*, from the coal-formation, that the testa is "thick, homogeneous, formed of fibres or elongated cells perpendicular to the surface. *These fibres appear, in one specimen, to be intermixed with little globular cells*, possibly in consequence of alteration of the tissue"*. This is precisely the appearance presented by the testa of *Pachytheca.* Brongniart's *Ætheotesta* is undoubtedly a seed, and he compares it with the nut-like seeds of Taxineæ.

Pachytheca has now been found associated with *Prototaxites*, not only at Corwen, but also in the Upper Ludlow of England, in the Upper Silurian of Cape Bon Ami, and in the Lower Devonian of Bordeaux Quarry opposite Campbellton in New Brunswick; and since the structure of the Corwen specimen corresponds with that of *Pro-*

* Annales des Sciences, tome xx. série 5.

totaxites, the presumption becomes strong that the connexion is not accidental. Under these circumstances, and considering the Taxine affinities of *Ætheotesta*, it would seem that *Pachytheca* may be accepted as affording some corroboration of the gymnospermous nature of *Prototaxites**.

Dr. Hicks has also sent a specimen of the so-called "microspores" found with *Pachytheca*. They occur in this specimen in a little semicircular patch or group, and are represented by mere impressions without any trace of organic matter. The lobed or furrowed appearance which they present gives to some of them the aspect of tetraspores enclosed in mother-cells, like the "*Triplosporites*" of Brown, in which case they might, as suggested by Mr. Carruthers, be Lycopodiaceous; but these furrows are so irregular that they may be accidental wrinkles. The occurrence of these objects in patches or groups suggests affinities with the *Parka decipiens*† of Fleming, a Devonian fossil at one time believed to be vegetable, but more recently referred to ova of Crustaceans. Similar groups of small rounded bodies occur in the Devonian of Gaspé; but I have not been able to decide as to their nature.

Discussion.

The President referred to the wide interest which the discoveries of Dr. Hicks had evidently excited.

Mr. Carruthers referred to a specimen sent to him by Dr. Dawson, which had its structure beautifully exhibited externally from weathering, and which he hoped to study by means of sections. He thought that Dr. Dawson's ideas were the result of having examined the specimens by imperfect means. He insisted that the minute structure of these plants was quite different from that of Conifers. The stems are made up of interlacing tubes; the smaller, which crossed the larger obliquely, were not spiral fibres inside wood-cells as supposed by Dr. Dawson. He thought no one acquainted with the minute structures of Coniferous wood and of Algæ could be led to accept the views of Dr. Dawson. The pseudo-exogenous structure is found in some living Algæ, as in *Laminaria*. With respect to *Pachytheca* he had always experienced great difficulty at arriving at any conclusion. He

* It occurs to me to add here that the beds in which *Prototaxites* is met with, in Gaspé and near Campbellton, contain no marine remains, but only land-plants; and though it would appear that in the Corwen beds the plants are associated with marine remains, yet the nature of the specimens sent to me is evidently of littoral rather than deep-sea character, and here also they are associated with land vegetation. These modes of occurrence, as I have elsewhere pointed out, are not in harmony with the supposition that in these plants we have to deal with great oceanic Algæ. Nor does this supposition accord with the fact that the wood of *Prototaxites* retains its form and is silicified in beds in which herbaceous land-plants are perfectly flattened.

† Lyell, 'Student's Elements,' p. 444; Nicholson, 'Palæontology,' vol. i. p. 382 (Dr. Hicks has, I see, made the same suggestions in his "Additional Notes," Quart. Journ. Geol. Soc., Feb. 1882).

thought that Sir Joseph Hooker was justified in referring it to Lycopodiaceæ from the materials at his command. He had long known that *Pachytheca* had a cellular structure filling its interior, consisting of tubular cells like those of the wall, but matted together. He was inclined to doubt whether they are really vegetable, and may not be animal remains. Mr. Storrie, of Cardiff, had sent him, years ago, well-preserved and beautifully prepared sections of *Pachytheca* showing the whole from centre to circumference; these led him to doubt their vegetable origin. He wished that zoologists would examine *Pachytheca*. He was satisfied, from the specimens on the table exhibited by Dr. Sterry Hunt, that the *Eopteris* of Saporta is really not a plant but a crystallization of pyrites, as suggested by M. Meunier-Chalmas.

Dr. Duncan remarked upon the wonderful discrepancies of opinion that prevailed. He did not regard the central part of *Pachytheca* as a mycelium. He regarded it as the float or conceptacle of a seaweed.

Prof. Judd stated that he exhibited, on behalf of Mr. Thiselton Dyer, two sections of *Pachytheca*. Mr. Thiselton Dyer regretted that he was unable to be present at the Meeting, but had sent Prof. Judd a letter, from which he read the following extract:—

"Kew,
November 15, 1881.

"I have to thank you for drawing my attention to the paper and discussion in the August number of the Quarterly Journal. Having read this, I venture to think that the specimens which I am placing in your hands my be found of some importance if exhibited at the meeting.

"Their history is briefly this. Some time ago Sir Joseph Hooker received from Mr. Grindrod a number of specimens of *Pachytheca in situ* on pieces of rock. As these examples of the fossils were apparently well preserved, two or three were detached and intrusted to Mr. Norman, who made the sections which are now in your hands. Sir Joseph Hooker did not see his way to any definite conclusion as regards the structure which they exhibited. He, however, allowed me to examine them, and they have since remained in my possession. The conclusion which I arrived at was that their structure agreed, in general plan, with that of *Codium*, as shown in Kützing, 'Phycologia Generalis,' pl. 42. f. 1.

"As a possible algal nature has been suggested for *Pachytheca* by Mr. Etheridge, I think it may not be considered presumptuous on my part to now state that I have been of opinion, ever since I studied the sections, that *Prototaxites* and *Pachytheca* are both referable to the same morphological type of structure. The radiating cells in the latter terminate internally in loosely interlacing slender filaments, with which the central cavity has been apparently filled. *Pachytheca* does not resemble any type of sporangium with which I am acquainted; the structure, as displayed in the specimens, has a certain resemblance to that of the sporocarp of *Pilularia*; but I cannot reconcile what I have seen of it with the supposition that it

was a reproductive structure belonging to any type of vascular cryptogam.

"According to the view which I take of *Pachytheca,* it was an algal organism, closely resembling in essential structure a diminutive *Codium*, but with the peripheral cells branched instead of simple. I do not see any evidence to lead me to suppose that it was related to *Prototaxites* as a sporangial organ. The existence of *Prototaxites* on modern biological views necessarily implies the existence, at some time or other, of allied forms; and I do not see why *Pachytheca* should not have been a contemporaneous one."

Dr. Hicks explained the way in which the specimens had come into Principal Dawson's hands.

The President supported Mr. Carruthers's views as to the non-coniferous character of *Nematophycus*. With regard to *Pachytheca* he felt great doubts.

10. *The* Red Sands *of the* Arabian Desert. By J. Arthur Phillips, Esq., F.R.S., F.G.S. (Read December 21, 1881.)

The Nefûd, or great red desert of Northern Arabia, commencing about four hundred miles east of Sinai, extends from the walls of Lina in the east to Teyma in the west, and from the edge of the Jôf basin in the north to the foot of Jebel Aja in the south. Its extreme breadth is 150 miles, and its greatest length 400 miles; but the whole of this area is not composed of continuous sands. The most eastern portion of this desert (and probably its most western extremity also) consists of a series of long parallel sand-drifts from half a mile to five miles in width, separated by intervening strips of solid plain.

Palgrave describes the Nefûd as "an immense ocean of loose reddish sand unlimited to the eye, and heaped up in enormous ridges running parallel to each other from north to south, undulation after undulation, each swell two or three hundred feet in average height, with slant sides and rounded crests furrowed in every direction by the capricious gales of the desert. In the depths between, the traveller finds himself, as it were, imprisoned in a suffocating sand-pit, hemmed in by burning walls on every side, while, at other times, while labouring up the slope, he overlooks what seems a vast sea of fire swelling under a heavy monsoon wind and ruffled by a cross-blast into red-hot waters"*.

Lady Anne Blunt, in her 'Pilgrimage to Nejd,' remarks with regard to this desert, "the thing that strikes one first about the Nefûd is its colour. It is not white, like the sand dunes we passed yesterday, nor yellow, as the sand is in parts of the Egyptian desert, but a really light red, almost crimson in the morning when it is wet with the dew"†.

She subsequently describes the great horseshoe hollows ("fuljes") scattered all over its surface, which, although varying from an acre to a couple of hundred acres in extent, are precisely alike in shape and general direction.

They exactly resemble the track of an unshod horse, the toe being sharply cut and nearly perpendicular, while the rim of the hoof gradually tapers to nothing at the heel, the frog being roughly represented by broken ground made up of converging dried up water-courses. The diameter of some of the largest of these depressions is fully a quarter of a mile, and the depth of the deepest, measured by Mr. Wilfred S. Blunt, proved to be 280 feet, thus bringing their level down almost exactly to that of the gravelly plain, which is doubtless continued beneath the sand.

The thickness of the sand is described as being by no means every-

* Palgrave (W. Gifford), 'Narrative of a Year's Journey through Central and Eastern Arabia,' p. 62.

† 'A Pilgrimage to Nejd, the Cradle of the Arab Race,' vol. i. p. 156; by Lady Anne Blunt. London: 1881.

where the same, since the intermittent parallel ridges before referred to are comparatively shallow, while their depth bears a constant relation to their width. The highest sand ridge by the Haj road is estimated at barely eighty feet, while others are but twenty feet in depth; on the other hand the continuous Nefûd between Jôf and Haïl has a depth of at least two hundred feet. Mr. Blunt suggests that these intermediate ridges may possibly throw some light upon the original formation of the mass. It would appear, he thinks, as if the wind acting upon the sand first drove it into lines, and these growing broader and deeper at last filled up the intervening spaces and formed themselves into a continuous desert*.

Although the Nefûd has been described as a totally barren waste, recent travellers state that it is everywhere, excepting on the highest summits of the sand hills, thickly sprinkled with brushwood, garda-trees, and tufts of grass, the "fuljes" being especially well clothed with vegetation.

From this circumstance, from the fact that sticks, stones, and other objects left upon the surface remain for many years uncovered, and that in crossing the desert the same landmarks are constantly made use of, Mr. Blunt concludes that at the present time these sands are not subjected to any material change of position from changes in the direction of the winds. He is moreover of opinion that although wind has at some time unquestionably caused the formation of the Nefûd, it now represents a state of comparative repose, as the winds which formerly heaped up these immense masses of sand were more violent than those which now prevail.

A specimen of Nefûd sand taken between Jôf and Haïl, for which I am indebted to the kindness of Lady Anne Blunt, was found to be composed of well-rounded distinctly red grains, varying in size from $\frac{1}{50}$ to $\frac{1}{30}$ of an inch along their greatest diameter. Some few of these grains have evidently been broken, and the resulting sharp edges have again become partially rounded.

By treatment with hydrochloric acid this sand becomes colourless; and on estimating the ferric oxide thus removed from a given weight, it was found to amount to ·21 per cent., or a little more than $\frac{1}{500}$ of the total weight of the material operated upon. In addition to ferric oxide a small quantity of alumina was removed by the acid.

It is consequently evident that the superficial coating of oxide of iron must have been formed subsequently to the period at which the rounding of the siliceous grains had been completed.

In order to ascertain to what extent this covering of ferric oxide could have resulted from the external decomposition and oxidation of the materials constituting the grains themselves, an analysis was made of the dried sand remaining after the attack by hydrochloric acid. This analysis afforded the following results:—

* *Op. cit.* vol ii. Appendix, p. 24.

Silica	98·53
Protoxide of Iron	0·28
Alumina	0·88
Lime, Magnesia, and Alkalies	traces.
	99·69 *

It follows, therefore, not only that the external coating of ferric oxide must have been deposited subsequently to the rounding of the sand, but also that it could not have been derived from an external decomposition of the grains themselves, since the total amount of iron which they contain scarcely exceeds that removed from their surfaces by digestion in dilute acid.

Seeing that the oxide of iron cannot have been the result of chemical action upon the sands themselves, it becomes somewhat difficult to imagine whence it can have been derived. The rounded grains covered by a coating of iron oxide, readily removed by hydrochloric acid, exactly resemble those of some of the "millet-sandstones" of Triassic age. In the latter instance, however, the iron has doubtless been deposited either during a period of submergence or subsequently by percolation from overlying strata, both of which conditions would, in the case of the Nefûd, appear to be improbable.

Discussion.

The President asked if any one present was prepared to offer a suggestion as to the origin of the iron coating the grains.

Rev. A. Irving suggested that vegetation might be the agency by which the iron was separated and deposited on the sand grains.

Mr. Drew pointed out that the action of vegetation on the sands of the Bagshot beds was to bleach, and not to colour them with oxide of iron.

Prof. Seeley suggested that slight solution of the grains might have taken place owing to the constant deposition of dew on these sand grains, which would assist in rounding them and leave the surface coated with iron oxide.

Prof. Morris said that in few of the old sands and sandstones were the quartz grains perfectly rounded. He referred to some crystalline sandstones of Penrith, and suggested that they might be derived from limestones, in which such crystals are often developed. Certain French geologists have suggested an eruptive origin for some Tertiary sands in which also prisms of *quartz* occur.

Dr. Hicks pointed out that in nearly all the old rocks most of the grains were but slightly rounded, and some tolerably perfect crystals also were generally present.

Mr. Phillips said that the most remarkable thing about the sand

* The amount of material at my disposal was not sufficiently large to admit of the estimation of substances present in very small quantities only.

grains was their completely rounded character, and the fact that the iron was chiefly present on the outside. There is generally more iron oxide on the grains of the millet-seed sandstones of the Trias than on the desert sand. If Prof. Seeley's suggestion were to be adopted we must suppose that each grain of the sand was originally twice as large as at present. The only cases in which he had found the smallest grains of a sand rounded were in wind-blown sands. He pointed out that it would require the solution of enormous quantities of limestone to produce the thick beds of crystalline sandstone which had been referred to.

11. *The* Torridon Sandstone *in relation to the* Ordovician Rocks *of the* Northern Highlands. By C. Callaway, Esq., M.A., D.Sc. Lond., F.G.S. (Read December 21, 1881.)

The late Sir R. I. Murchison and his co-worker, Prof. A. Geikie, came to the conclusion that the Sutherland quartzites rested unconformably upon the Torridon Sandstone, and from this break in the succession they inferred that the latter was the equivalent of the Longmynd or Harlech series, the Upper Cambrian being wanting. In some localities the sections, seen from a distance, seem to confirm their opinion; but a careful and detailed examination made last summer convinced me that, in some localities at least, this appearance is deceptive, and that the sandstone passes up with perfect conformity into the quartzite. I was accompanied during my work by Mr. G. H. Bailey, B.Sc., of Tettenhall College, to whom I am indebted for much intelligent and active assistance.

Loch Broom.

Looking up at the section from the road, near the Ullapool Hotel, the quartzite is seen to dip east-north-east at 15°, while the Torridon seems to lie in horizontal beds. This appearance of the latter is due to a number of grooves, many of them horizontal, which cross the face of the sandstone cliff and suggest bedding. On a closer investigation the true stratification, as indicated by the principal pebble bands, is found to be conformable to the overlying quartzite. Besides this, we have the clearest evidence of a gradual passage between the two groups. The Torridon, which is mainly made up of quartz and felspar, grows more quartzose towards the top, and passes into the basement beds of the quartzite, which contain scattered grains of felspar and graduate upwards into pure quartzite. Some of the passage beds are of so intermediate a character that it would be impossible to refer hand specimens with certainty to either series.

Further to the west, in the quarries above the village, the sandstone is well exposed, and, though the stratification is much obscured by current lamination, it is seen to be in conformity with the quartzite.

Strath Auchall.

The junction of the two series may be well studied on the north side of the valley which runs up from Ullapool to Loch Auchall. The sandstone passes under the quartzite with perfect conformity, the dips of both being unmistakably clear; and here also we have the gradual lithological passage seen on Loch Broom. But this section furnishes an additional proof of continuity. Both groups

display very distinct current-lamination, and at one spot the lamination (dipping easterly at 45°) in a bed forming the base of the quartzite is parallel to the lamination in the bed of sandstone which immediately underlies; so that it would appear as if the same current which threw down the stratum of felspatho-quartzose sand, after an interval deposited the bed of quartzose sand.

Following the quartzite up the valley, we come to an abrupt hollow in the hillside, and on the opposite slope we again reach the Torridon, thrown up by a fault, and the conformable upward passage into quartzite is repeated.

Between Ullapool and Strath Kennort.

The Torridon Sandstone is well seen for several miles along the road from Ullapool to the north. The bedding is quite distinct, the dip still being steady at an angle of from 10° to 15°, at first to east-north-east, and then, towards Strath Kennort, to the south-east. Nowhere did we observe horizontal stratification.

North side of Loch Assynt.

On the south slope of Queenaig there is, as at Ullapool, a superficial appearance of unconformity, which vanishes on examination. Towards the base of the quartzite, angular bits of felspar begin to come in abundantly, and the rock assumes the form of a quartzo-felspathic grit, as on Loch Broom. We first worked along the section at an elevation of about a hundred yards above the road, and at this level the sandstone for some distance seemed to lie horizontal; but as the rock was full of current lamination, the true bedding was difficult to determine. At about a quarter of a mile to the west of the junction, the obscurity disappeared, and the lower part of the Torridon, consisting of flaggy beds and more aluminous in composition, was observed to dip in conformity with the quartzite. This inclination was steadily maintained right down to the Lewisian gneiss. I then worked back towards the quartzite at the level of the road, and, when possible, on the shore of the loch. Along this line, the conformity of the sandstone to the quartzite is quite clear. The appearance of horizontality at the higher level was puzzling, but it is apparently connected with current-lamination. It is at any rate quite certain that where this lamination is absent, the bedding of the Torridon is distinctly parallel to that of the quartzite.

It will perhaps help to explain some difficulties to observe that the dip of the rocks gradually decreases as we descend in the series. The usual dip of the upper part of the quartzite is 15°, which towards the base diminishes to 10°. The underlying Torridon Sandstone sometimes reaches 10°. It is usually rather lower, but even at its base it is not less than 5°, and it dips throughout in the same direction (east-north-east) as the quartzite.

In this district, as at Ullapool, the quartzite is frequently full of current-lamination. The persistence through the two series of the same conditions of deposit adds something to the evidence in favour of their conformity.

South of Unapool.

A few miles to the north of the last locality, on the slope above Unapool, the Torridon Sandstone, which has rapidly thinned out to a few score feet, dips to the south-south-east at 10°, the quartzite overlying it with perfect conformity and containing grains of the usual red felspar at the base.

Summary of Evidence for the Conformity.

In every section examined the following facts were observed :—

1. Perfect agreement of dip between the sandstone and the quartzite.

2. A gradual lithological passage from pure quartzite through quartzo-felspathic grit into ordinary Torridon Sandstone.

In most localities it was also noticed that,

3. Similar conditions of deposit prevailed through both formations, as seen in the frequent presence of cross lamination.

It is also important to point out that,

4. Change of dip in one group is, so far as these observations extended, uniformly accompanied by the like change in the other. Thus, while both series dip to the east-north-east in the Ullapool and Assynt districts, the inclination of both is to the south-south-east above Unapool.

Age of the Torridon Sandstone.

If I am justified in the above conclusion, it is obvious that the Lower Cambrian age of the Torridon can no longer be maintained. It is generally admitted that the fossils of the Durness Limestone* determine the Arenig age of the quartzo-calcareous series. The Torridon must then be either Upper Cambrian or basement Ordovician. In the absence of fossils, it will be difficult to settle the question ; but the physical evidence seems to me to be against the Cambrian age. For, in the first place, both the Torridon and the quartzite, being full of oblique lamination, must have been quickly accumulated. The rapid thinning out of the former and the frequency of conglomerates point to the same conclusion. Besides this, it will, I think, be found necessary to reduce the usual estimates of the thickness of the deposits. On Loch Assynt, the Torridon Sandstone does not exceed 1000 feet, most of which must have been rapidly thrown down. Should the thickness elsewhere be doubled

* This argument takes for granted the generally received view that the Durness and Assynt limestones are of the same age. This is denied by Prof. Heddle (Mineralogical Magazine, Aug. 1881).—C. C., March 28, 1882.

or even trebled, the question would not be materially affected, since, in these shore-deposits, great accumulations may be formed in a few millenniums. The overlying quartzo-calcareous series nowhere, I believe, reaches a maximum of 500 feet, the great prominence which it assumes in the lofty mass of Ben More of Assynt being due to frequent repetitions by faulting and folding. Accepting an extreme estimate, the united sandstone and quartzite will hardly exceed the thickness of the Arenigs of Shropshire, which, composed mainly of shales and fine-grained flags, must have been accumulated with much less rapidity; and the Highland groups must fall short of the Arenigs of South Wales, which Dr. Hicks calculates at nearly 4000 feet. There would therefore appear to be no sufficient reason for separating the Torridon Sandstone from the Ordovician system.

Discussion.

Mr. Hudleston said that Dr. Heddle maintained the unconformity of the quartzites with the Torridon Sandstone, and he was extremely well acquainted with the district. This was a question of evidence which could hardly be brought before the meeting; but as regards the age of the sandstone it was possible that the limestones over the quartzites were not of the same age as the Durness Limestone; the old statements as to fossils having been found in the limestone and quartzite group did not seem to have been substantiated. The chemical composition of the two differed; the fossiliferous limestone of Durness was not dolomitic, the others were, containing sometimes 48 per cent. of carbonate of magnesia; if these are different the theories built upon their supposed identity fall to the ground.

Mr. Drew asked if Dr. Callaway had visited the same section that Sir Roderick Murchison had described.

Dr. Hicks said that he thought if Dr. Callaway had carried his sections further south he would have seen unconformity. In the neighbourhood of Loch Maree the Torridon Sandstone was nearly 4000 feet thick, and the quartzite within a very short distance rested directly upon the gneiss, so that an unconformity was needed. He could not agree, however, with the views of Dr. Heddle as to the non-identity of the limestone of Durness with that of the other districts. He thought that the Torridon Sandstone represented the Lower Cambrian, and the quartzite series, which contains evidences of worm-tracks, some part of the Lower Silurian.

Prof. Bonney said he agreed with Dr. Hicks in thinking that the Loch-Maree quartzites were unconformable with the Torridon Sandstone; at the same time he was prepared to believe there was conformity further north. He believed, from microscopic examination, that the limestone in Glen Laggan was dolomitic, and thought that Prof. Heddle's solution of the question was the right one. He could not think the Torridon Sandstone Ordovician; at any rate, if it were, Dr. Callaway must accept the following dilemma, either

that some 3000 or 4000 feet of Torridon Sandstone and quartzite had completely thinned out in a very short distance (less than three miles), or that the newer gneiss, which overlies the limestone, is, as the Survey stated, Lower Silurian.

Dr. Callaway said that when Dr. Heddle was present he would be glad to discuss the question. He did not feel able to express an opinion as to the age of the newer gneiss. The section described by him at Assynt was identical with that described by Sir R. Murchison. There might or might not be unconformity about Loch Maree; all he said was that in the more northern districts there was none. He was prepared to admit that the Torridon Sandstone had thinned out with great rapidity. This was well seen north-east of Queenaig, where the sandstone, less than 50 yards thick, passed unconformably under the quartzite.

12. *The* PRECAMBRIAN (ARCHÆAN) ROCKS *of* SHROPSHIRE. Part II. By C. CALLAWAY, Esq., M.A., D.Sc. Lond., F.G.S. *With* NOTES *on the* MICROSCOPIC STRUCTURE *of some of the* ROCKS, by Prof. T. G. BONNEY, M.A., F.R.S., Sec.G.S. (Read December 21, 1881.)

IN 1879*, I announced to the Society that the volcanic rocks of the Wrekin, originally supposed to be "greenstone," and which had recently been described by Mr. S. Allport † as bedded lavas and ashes, were Precambrian, and I showed that rocks of the same age, associated with gneissic strata of still higher antiquity, formed a chain of hills nearly thirty miles in length. In the following year, in a paper ‡ "On a second Precambrian group in the Malvern Hills," I sketched the history of the physical changes which the Shropshire range, in common with the Malvern chain, had undergone, and I correlated the Salopian gneissic and volcanic series respectively with the metamorphic axis of Malvern and the felspathic mass east of the Herefordshire Beacon. Further attempts at correlation have not led to decisive results; but it is indubitable that there are strong lithological analogies between the Wrekin series and the Archæan rocks south of Bangor, as well as between the Lilleshall group and the Charnwood and St.-David's volcanic series. My present object is to describe a second area of Archæan rocks lying further to the west, and in so doing to present additional evidence of the Precambrian age of the whole group.

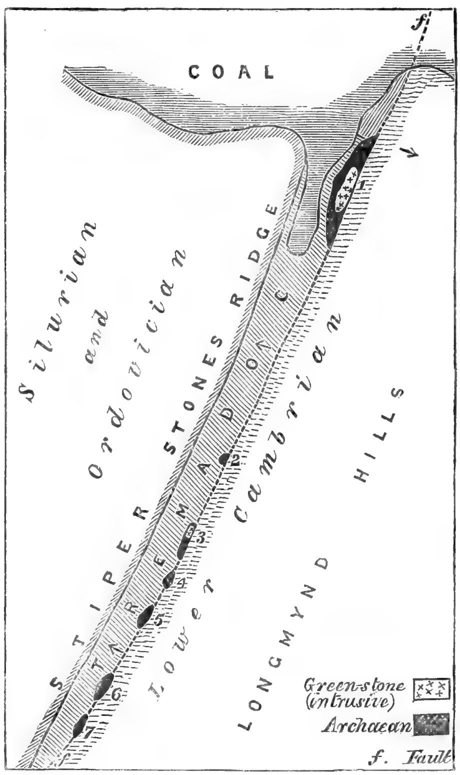
a. *General Description of the western Archæan Axis of Shropshire.*

The rocks of this area are exposed at intervals along a line which runs roughly parallel to the Wrekin and Caer-Caradoc chain, at a distance of from 6 to 7 miles, the strip of country which lies between being chiefly occupied by the Longmynd group. Looking at the Survey Map, it will be seen that down the valley between the Longmynd and the quartzite ridge of the Stiper Stones is drawn the boundary between the Longmynd series and the formation which Sir R. I. Murchison and the Survey described as Lingula Flags, but which by its fossils is proved to be the equivalent of the Shineton Shales (Tremadoc). At intervals along this line are put in patches of "greenstone," most of which prove to be Archæan rocks of varied character; but occasionally the Archæans appear at spots coloured as Cambrian (Longmynd). From this ancient axis the Longmynd rocks and the Tremadoc are thrown off in opposite directions. From the most northerly exposure of the Archæan, near Pontesbury, to the southern end of the chain, near Linley Hall, the distance is about 11 miles. Usually the old rocks form low hills or ridges

* Quart. Journ. Geol. Soc. vol. xxxv. p. 643.
† *Ibid.* vol. xxxiii. p. 449. ‡ *Ibid.* vol. xxxvi. p. 536.

trending to the south-south-west, which are generally inconspicuous owing to the greater height of the parallel ranges of the Longmynd and the Stiper Stones on either side; but Pontesford Hill, which is partly Archæan, projects into the plain surrounding Shrewsbury as a prominent outlier from the mountain district of western Shropshire, corresponding geographically, as it does geologically, to the Wrekin in the eastern chain. The position and relations of the masses of Archæan rock exposed along the axis are shown in the accompanying map. Some of the boundaries are necessarily approximations.

Sketch Map of the Western Archæan axis of Shropshire.
(Scale, $\frac{1}{3}$ inch to a mile.)



Microscopic notes on some of the principal rock types are kindly furnished by Prof. Bonney, F.R.S. It is very satisfactory to be able to state that his conclusions, formed upon slides alone, agree precisely with my field-determinations.

b. *Detailed Geology of the Axis.*

1*. *Pontesford Hill.*—This elevation is about one mile in length

* This and the following numbers (1–7) correspond to the numbers in the map.

from north to south, and is coloured on the Survey Map as "greenstone." At the north end, there are good exposures of purple rhyolite, banded and spherulitic (no. 56, p. 124). The resemblance of this rock to the Wrekin lavas, and especially to the type at Lea Rock, near Wrockwardine, is unmistakable. In the quarry below the road, there is apparent bedding with a south-west dip and some contortion. Above the road, a highly spherulitic variety is well seen in the hill-slope. The spherules are frequently of chalcedony. Similar concretions, together with a smaller proportion of agate, are found as derived fragments in the Lower Cambrian conglomerates of Haughmond Hill, near Shrewsbury. A little higher than the spherulitic type, the rhyolite is clearly banded, the flow-lines dipping to the south-south-west at 45°.

The summit of the northern spur of the hill is occupied by compact dolerite (basalt) (no. 57, p. 124); and similar rock is to be traced along the ridge to the top of the mountain. This mass is apparently intrusive; and as it is not found in the neighbouring Cambrian conglomerates, it is probably Postcambrian. Doleritic rocks, some highly altered, are also exposed on the western slope of the ridge. On this side of the hill I also noticed compact felsite and hornstone of ordinary Archæan types.

The structure just described, a plagioclinal ridge broken through by intrusive greenstone, agrees with the formation of the Wrekin, the Lawley, Caer Caradoc, and other elevations of the eastern axis.

At Lyd's Hole, a picturesque ravine, with a cascade, situated about half a mile east of the north end of the hill, the purple rhyolites (no. 55, p. 124), banded and highly spherulitic, are finely exposed in the crags overhanging the stream. The flow-lines dip south-easterly at 80°. Just above the fall is a junction of the Archæans with purple sandstones and shales of Lower Cambrian age, which dip as if in conformable succession. I believe, however, for reasons which cannot here be enumerated, that the two groups are faulted together, so that the conformity of dip is merely a coincidence. Following up the stream to the south-east, we pass over several hundred feet of the Cambrian; and west of Ratcliff we come to a conglomerate dipping at a high angle to south-south-east. Pebbles of quartzite and purple rhyolite predominate; but green slate and mica-schist also occur. A little higher in the series, there is a second conglomerate, dipping at a lower angle, from 50° to 60°. The composition is similar; but the pebbles are larger, some of them reaching the size of a child's head. The purple felsite of this conglomerate is very characteristic, and is undoubtedly derived from the Archæan volcanic group.

A short distance north of Lyd's Hole, there occur stream-sections of greenish shale containing *Trinucleus concentricus*, *Orthis testudinaria*, *Diplograptus pristis*, and *Beyrichia complicata*, an assemblage characteristic of the Harnage Shales (Lower Caradoc), with which these rocks agree also in their lithology. In Murchison's 'Silurian System' it is stated that at this spot intrusive "greenstone" has "caught up fragments of shale," a singular reversal of the true facts.

There is no intrusive rock near; but pebbles of rhyolite (no. 58, p. 124) are contained in the shale. Some of the rhyolite is banded; and these enclosures are, I believe, derived from the Archæan.

In a field to the north-east of the Caradoc shale is a small exposure of micaceo-arenaceous flags of a dark grey colour, dipping south by a little east, and probably belonging to the Arenig series.

I have called attention to these detached fragments, occurring on the strike of the Tremadoc shales, as indicating the powerful dislocations which have ruptured the rocks along this Archæan axis.

2. *Gatten Lodge.*—Following the axis in a southerly direction, we come, in about three miles, to a small elevation near Gatten Lodge. Rock is exposed in a quarry near the road, with an apparent dip to the north-east. The prevailing type (no. 59, p. 125) is purplish and compact, resembling the flinty hornstone-like rock so common in the Pebidian. In places it is brecciated, the fragments, some of which are subangular, being of quartz and the purple hornstone.

3. *Knolls Ridge.*—The next Archæan mass occupies part of a ridge which I have named from a house at its north end, lying a mile and a half south-south-west of Gatten Lodge. It is about one mile long, striking with the axis. The rocks of which it is composed are varied and generally difficult of determination. Some are intrusive. At the north end is a greenstone allied to diorite (no. 60, p. 125). Felsitic rocks occur further along the ridge. At the south end is a purplish hornstone, similar to the Gatten-Lodge type.

4. *Cold Hill.*—West-north-west of the farm of Cold Hill, on the line of fault continuous with Knolls Ridge, there is a slight exposure of purple hornstone and breccia.

5. *Chittol.*—In this hill, about a mile from the last locality, is found a greenish compact rock, which I believe to be sedimentary. It has the splintery fracture characteristic of the hornstone-like rocks of the Pebidian, to which it is probably to be referred.

6. *Knolls Wood.*—This locality is a mile further to the south-south-west. The rock is hard and compact, and on fractured surfaces looks like a quartz-felsite; but where weathered it is seen to be clastic, bits of quartz and of a reddish granitoid rock being clearly visible. The latter variety is not unlike the (presumed) Dimetian of the eastern axis. Some of the fragments display a foliated structure. Altered grits similar to this rock occur in the Caer-Caradoc chain; and as the strikes in both localities are the same (east and west), and if produced would coincide, it is probable that the rocks of Knolls Wood occupy about the same horizon as those of Caer Caradoc.

7. *Ridge west of Linley Hall.*—This elevation, one mile from the last locality, forms the termination to the south of the western Archæan chain of ridges. It is composed mainly of hornstone or hälleflinta (no. 61, p. 125), purple and green, which does not quite so closely resemble the hornstone previously described as it resembles certain varieties in the Wrekin, Lilleshall Hill, and the Malverns. The Archæan is broken through by dolerite.

The purple conglomerate east of Pontesford Hill, in its course

southward, approaches more and more closely to the Archæan axis; and at Knolls Ridge and Cold Hill it is almost in contact. This is one evidence of the want of conformity previously suggested. The conglomerate does not materially vary towards the south, being still composed of quartzite and purple felsite, and nowhere containing, so far as I have observed, fragments derived from the hornstone. This is not what we should expect if, as might at first be inferred, the conglomerate were the base of the Cambrian, and formed as a shore-deposit along the Archæan axis.

I have stated that the strike of the Archæan, wherever observed, except at Lyd's Hole, is east and west or south-east and north-west, while the adjoining Cambrians, Upper and Lower, strike south-south-west, the great fault and the Archæan ridges also trending in the same direction. The formation of the fault and the upthrust of the Archæans would therefore seem to be connected with the forces which at the close of the Ordovician epoch threw the Ordovician and Cambrian deposits into folds, and determined the direction of the older mountain ridges of Shropshire. I cannot, however, speak positively on this point, since powerful earth-movements have taken place in this district along the same lines at different epochs.

It will have been noted that, as is so frequently the case with Archæan elevations, the structure of the ridges described is plagioclinal.

Summary of Results.

1. On a south-south-west line running between Pontesbury and Linley Hall are seven distinct elevations, composed wholly or in part of Archæan rocks.

2. This line corresponds with a great fault, on the east side of which Longmynd rocks dip easterly, and on the west Tremadoc shales dip westerly.

3. The prevailing rock-types are purple rhyolites at the north end of the chain, purple hornstone (or hälleflinta) in the middle, and purple and green hornstone (or hälleflinta), with some indurated grits, partly derived from a gneissic series, at the south.

4. The Precambrian age of these rocks is proved by their close lithological affinities with known Salopian types, and by the almost universal occurrence of fragments of the purple rhyolites in the Longmynd series. The strike, also, is usually more or less transverse to the strike of the Cambrian deposits.

5. The rocks of this axis belong exclusively to the younger of the two Salopian Archæan groups, no traces of granitoid or gneissic rocks, except as included fragments, having been detected.

Appendix.

Notes *upon some* Specimens *of* Shropshire Rocks.
By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

(55) *Lyd's Hole, Pontesbury.*—A rhyolite, with well-marked fluidal structure, much stained with ferrite and with occasional patches of opacite. The rock exhibits a devitrified structure, the crystallites in most parts assuming an acicular form, the majority no doubt being felspar; but some, of a pale golden colour, must be a different mineral, possibly a mica allied to sericite. There seems in parts a tendency to a microspherulitic and even micrographic structure; the ferruginous constituents assume many forms, from mere specks to little rods and granules. There are two or three larger crystals of felspar, containing apparently glass inclusions; the fluidal bands are crossed transversely by a much more deeply stained zone. The rock has a general similarity to those common in the neighbourhood of the Wrekin.

(56) *Pontesford Hill, North-End Quarry.*—A remarkably beautiful specimen. The slide gives a complete section of an elongated cavity filled with chalcedony. The enclosing border of rock is a rhyolite; this has a fluidal structure parallel to the longer axis of the concretion, is deeply stained with ferrite, and exhibits in its crystallites indications of radial structure normal to the longer axis; within this is a zone of chalcedony, sometimes containing fragments of the rhyolite, the microliths of quartz being grouped in radiating tufts like the hairs in a sable-brush, a familiar appearance in agates: in places also they form regular spherulites; within this is an enclosure of minutely crystalline quartz. These hollow spherulitic concretions, subsequently partially or wholly filled by infiltrated minerals, are not uncommon in acid lavas; and I have been for some time engaged upon the study of a somewhat similar group from North Wales. The rock of Lea Hill, in the Wrekin district, is very similar in structure to this one from Pontesford Hill.

(57) *Pontesford Hill* (summit).—The ground-mass is full of elongated microliths of felspar with a slightly parallel grouping, generally plagioclase, but possibly in one or two cases orthoclase, with dark granules, probably in many cases hæmatite, and numerous grains (generally rather irregular in outline) of augite. One of more definite form is a compound crystal about ·02 inch in diameter. There is a small quantity of a chloritic mineral. The rock is a basalt, and more resembles that of a flow than of a dyke.

(58) *North of Lyd's Hole, Block in Caradoc Shale.*—The structure of this rock is a little abnormal. With ordinary light it exhibits a clear base containing a multitude of dark specks, evidently ferruginous, some being brown (probably the hydrous peroxide of iron) others nearly black. These are so arranged as to give a spotted aspect to the slide. On using crossed Nicols the spots containing the latter prove to be devitrified patches of one or more crystals, very imperfectly developed.

The browner spots remain dark, but contain many extremely minute (felspar ?) microliths. In places the devitrified structure occupies the whole of irregular zones in the slide; in others there is a considerable amount left of the apparently unaltered base. This closely resembles a fluidal structure. On the whole, therefore, I consider this a fragment of rhyolitic lava, parts of which may still remain in a glassy state.

(59) *West of Gatten Lodge.*—A sedimentary rock, with the structure characteristic of the argillites or whetstones which occur in parts of Charnwood Forest, the rock being made up of innumerable minute granules, probably of quartz, and specks of ferrite. Larger fragments are also present: some resemble bits of a rather similar rock; others may be only patches where the staining is more pronounced; many are quartz, subangular in form; and two or three much resemble bits of rhyolite.

(60) *North end of Knolls Ridge.*—A rather coarsely crystalline rock, consisting to a large extent of a plagioclastic felspar. This is evidently decomposed; and the crystals enclose numerous microliths of epidote (of secondary formation); some exhibit a micrographic structure with quartz, such as is common in the syenites of Charnwood Forest. Grains of viridite are also enclosed. Larger patches of viridite are present, though not numerous, with a little quartz (this has more resemblance to an original constituent), some ilmenite and perhaps magnetite, and some apatite. Under the circumstances it is difficult to decide whether the rock should be called a diorite or a diabase; perhaps the former name is the safer, though it is by no means a typical example.

(61) *West of Linley Hall.*—In parts of this slide a very decided fragmental structure is visible. In these older rocks it is necessary to be always on one's guard to avoid mistaking the result of brecciation *in situ* (due to crushing, especially near faults) for an original clastic structure. I think, however, that there is here sufficient evidence of the latter. Minute crystals of epidote are not unfrequent, especially in the intervals between the apparent fragments. With ordinary light the ground-mass is clear and contains numerous specks of filmy golden-green mineral, and clotted spots of a dusty-grey or brownish mineral: part of the former is epidote; but some may be a variety of mica or chlorite, or possibly hornblende. With crossed Nicols the ground-mass exhibits a very minute devitrified structure. In this respect it has (except that distinct crystals of quartz or felspar are absent) a remarkable resemblance to some of the rocks from the Sharpley and Bardon districts in Charnwood Forest, especially to the more compact felstone-like varieties of the the latter*. I am disposed therefore to regard it as, like these, an indurated somewhat altered tuff.

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 209, vol. xxxvi. pp. 341–347.

Discussion.

The President said that Dr. Callaway's views would much alter the stratigraphy of the deep valley between the Longmynd and Stiper Stones. He had no doubt Tremadoc rocks were in that valley; whether the Stiper Stones were Upper Tremadoc or Arenig, and whether contemporaneous with the white grit of North Wales, was a dubious question; he invited discussion.

Dr. Hicks said he had but slightly examined the district. The paper was an important one. There appeared to be evidence of Precambrian rocks in contact with admitted Cambrian rocks; so that in this region also, as in the Welsh areas, we had a base-line. The paper was important also as showing that certain types of rocks were characteristic of the Precambrian groups over wide areas. Some years since he had expressed the view that the Stiper Stones were of Arenig age and about the horizon of the Grit-band of Caernarvonshire mentioned by the President.

Mr. Rutley said it struck him as possible that these rhyolite rocks occurred on the horizon of the Bala limestone. Also Mr. Allport had suggested that perlitic rocks, associated with beds mapped by the Geological Survey as Caradoc, were Precambrian. He thought it worth reconsidering whether these might not be really of Bala or Llandeilo age. The fragments might constitute old volcanic breccias or tuffs.

Prof. Bonney said that the rocks of the Wrekin were certainly agglomerates, and that fragments of the rhyolite certainly occurred in the so-called Wrekin quartzites, which he believed were now admitted to underlie Tremadoc rocks. Hence they could not be of Bala age.

Dr. Callaway said that he proposed on a future occasion to give more detailed sections of the country. As for Mr. Rutley's suggestion;—over the quartzite, which contained rhyolite fragments, was Hollybush sandstone, and over that, Tremadoc; further, rhyolitic fragments occurred in the conglomerate of the Longmynd, and even in the finer beds; so he thought the Archæan age of the rhyolites was proved beyond all question.

13. *On a peculiar* Bed *of* Angular Drift *on the* Lower-chalk *high* Plain *between* Upton *and* Chilton. By Prof. J. Prestwich, F.R.S., F.G.S., &c. (Read February 8, 1882.)

In making the new line of railway from Didcot to Newbury some sections of considerable interest were laid open between the main Great Western line and the village of Chilton. For the first three miles from Didcot the railway passes over the Upper Greensand, the lower part of which here consists of compact beds of greenish sandstone, and the upper part of beds of a light-coloured greensand, together probably more than 100 feet thick. Beyond these, at Upton, the Chalk without flints rises in a range of hills running east and west, through which the line is carried, exposing a fine section, a mile in length, of drift, Chalk-marl, and Lower Chalk* (see section fig. 1).

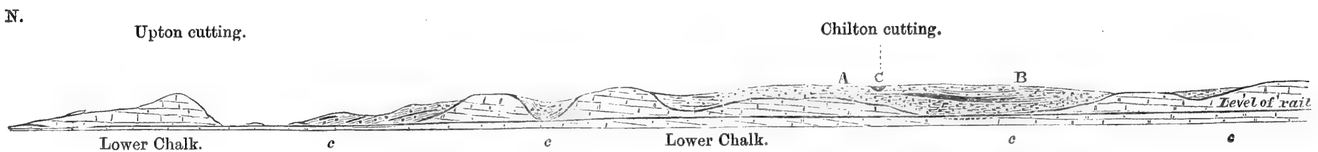
The point, however, of more particular interest is the great bed of drift indenting the chalk. It sets in one third of a mile south of Upton, and extends to a short distance beyond Chilton, a length of about $1\frac{1}{4}$ mile. It is a drift of a character so abnormal in this district that it deserves a short separate record. The tract it occupies forms part of the flat plain which here extends with a width of about two miles from the foot of the escarpment of the Upper Chalk with flints, near East Ilsley, to the edge of the lesser escarpment of the Lower Chalk without flints at Upton, above referred to (see section fig. 2). A small transverse valley here runs through these Lower-Chalk hills; but, though a line of drainage, it is without any permanent brook or stream, nor was there any distinct appearance in the railway-cutting (which at Upton was carried up this small valley) of there having been a stream here in former times.

In the first cutting the Lower Chalk rises bare to the height of 27 feet. The next cutting, which is from 10 to 20 feet deep, is through a white chalk rubble, fine and marly at base, coarser and with a few small angular fragments of flints at top. A little way beyond, the chalk comes up again through the drift, is again replaced by the drift, and again the hard grey chalk rises abruptly to the surface in a cutting 35 feet deep. Thus far the drift is very fine, more like decomposed Lower Chalk, and no organic remains were found in it in this part of the cutting.

Beyond, the characters begin to change; the drift becomes more coloured and somewhat coarser, and occasionally small boulders and bones were met with. A great number of bones were found together about two thirds down in this rubble drift about midway in the Chilton cutting, at the point marked A (see figs. 1 and 3, p. 129). A short distance further southward an intercalated darker clay bed

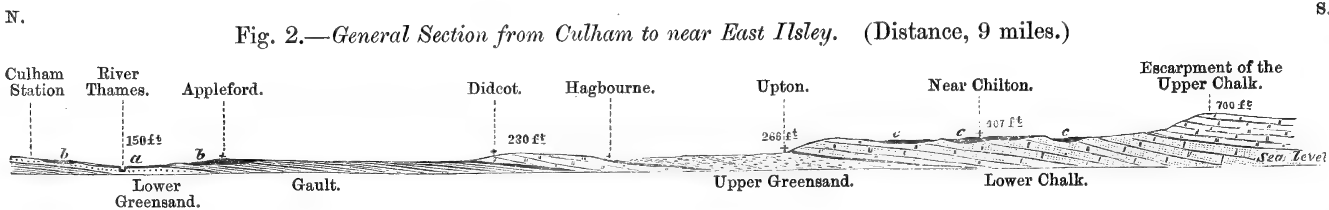
* Very few fossils had hitherto been obtained from the Lower Chalk of the Didcot district; but in this cutting they were, in places, abundant, especially *Ammonites varians*. Altogether we obtained 35 species from the Lower Chalk, and 23 species from the Upper Greensand, for the Oxford Museum.

Fig. 1.—*Railway Section from Upton to Chilton.* (Length, $1\frac{1}{2}$ mile. Scale of height, 1 inch =200 feet.)



a'. Rain-wash. *c*. Angular Drift.

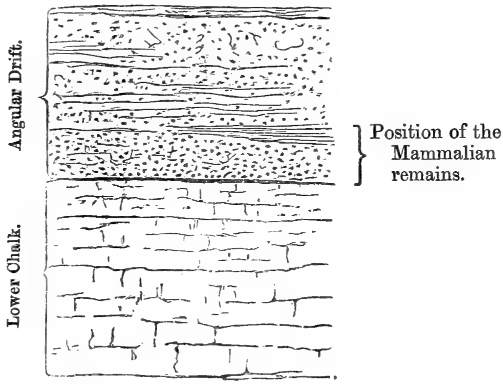
Fig. 2.—*General Section from Culham to near East Ilsley.* (Distance, 9 miles.)



a. Alluvial bed of the Thames.
b. Low-level Valley-gravel, with mammalian remains and river-shells in places.
c. Angular drift, with mammalian remains and land-shells.

set in (see fig. 4, p. 130), and divide the mass into a lower light-yellow coarser angular drift, and an upper whiter and finer drift, but both alike in composition, and both consisting of irregular roughly stratified beds. The works had extended to this point when the discovery of elephant-remains was reported to me.

Fig. 3.—*Section in Cutting at A, in fig.* 1, *enlarged.*



I took an early opportunity of visiting the spot; but the cutting had then gone beyond the place where the bones were found, and the sides were sloped over. The bones proved to be those of *mammoth, rhinoceros, horse, ox,* and *deer*. They were mostly in a broken and fragmentary state. But, though broken, they are not rolled or waterworn. The state of preservation of some of the bones is very remarkable; they have lost so little of their animal matter that the bone hardly adheres at all to the tongue, and looks almost as fresh as a recent bone. Dissolved in dilute hydrochloric acid, they leave a mass of flocculent gelatinous matter. This is more especially the case with some of the Bison bones, one of which comes from near the base of the cutting at point B (fig. 1)*. The specimens now in the Oxford Museum consist of—

Elephas primigenius	Some fragments of large bones.
Rhinoceros	Distal end of femur and other bones, all broken.
Equus	Teeth and fragments of bones.
Bison priscus?	Right metatarsal, distal end of metacarpal, left humerus, and right tibia.
Cervus tarandus	Tooth and fragments of antler.

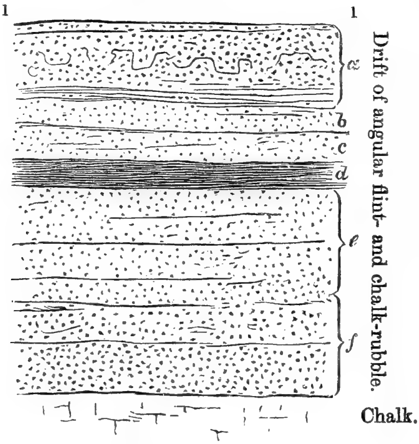
But a larger number have been found, including portions of two lower jaws and of tusks of Mammoth, teeth of Horse, end of humerus and 4 teeth of *Rhinoceros tichorhinus*, fragment of horn of Red Deer,

* A recent analysis of this specimen on the chemical side of the Museum shows this bone to contain 17·35 per cent. of organic matter. Recent bones of Ox contain about 30 per cent. Mr. Fisher also informs me that the bone contained a notable proportion of manganese.

4 teeth of Bison, and some undeterminable fragments. There are no traces of gnawing on any of the bones.

When I first visited the cutting the drift-exposure was at its deepest, extending to the base of the cutting, a depth of 28 feet, and just reaching the chalk beneath. The section it here presented is as under (fig. 4).

Fig. 4.—*Section in Cutting near the village of Chilton, at B, fig.* 1, *enlarged.*



		feet.
1.	Surface soil (reddish loam with a few flints)	½ to 1.
a.	Cream-coloured fine chalk- and flint-rubble, showing a deeply festooned or waved surface	6 to 10.
b.	Soft white marl (reconstructed chalk) with shells	4 to 6.
c.	Very light yellow chalk- and flint-rubble (with an occasional black band)	2 to 5.
d.	Dark brown clay (almost black in places), forming a line of separation between the lighter beds above and the darker yellow and brownish beds beneath; two specimens of *Pupa marginata*	2 to 4.
e.	Light-yellow flint- and chalk-rubble, fine; one *Pupa*	3 to 6.
f.	Coarser flint- and chalk-rubble; bone of *Bison*	5 to 10.

In the lower half of the drift there were found irregularly dispersed in various parts of the cutting a few blocks of very hard and compact Sarsen stone (Lower Tertiary Sandstone). Two of the largest measured 2 ft. × 10 in. × 9 in. and 1 ft. 9 in. × 1 ft. 6 in. × 10 in. The angles were rounded; but otherwise they were not much worn.

In the beds *c* and *f* were some grains of glauconite, derived probably from Lower Tertiary sands; and the clay of bed *d* may be derived from some of the Tertiary clays. The black band in *c* is caused by the admixture of a sooty manganese peroxide.

The fragments of chalk mostly vary from the size of a pea to that of a bean. Some, which consist of soft chalk, are worn and rounded; but others, which consist of a very hard chalk, are flat and sub-

angular. There is also a bed of chalk-rubble, in which are angular fragments of soft chalk.

All the fragments of flint, on the other hand, even the smallest (and there are few more than 2 or 3 inches in length), are *perfectly sharp* and *angular*, and are generally not discoloured. Some, however, are slightly whitened. The chalk débris predominates at the north end of the cutting, and the flint débris at the south end.

Few bones were found, except at the first place. They did not seem confined to one bed, though most of them were found in the lower part of the deposit.

There is no trace in any part of this section of stream- or river-action. With few exceptions, where the rubble forms a soft concrete, the whole mass is loose and incoherent like so much shingle. This condition continues to the very base of the section without difference, except that the rubble is there rather coarser and more coloured. Few of the beds were continuous for the whole distance. They generally formed lenticular masses of greater or less extent. It was in an intercalated mass of white marl, or chalk paste, at the south end of the Chilton cutting, and at a depth of from 8 to 12 feet from the surface, that almost all the shells were obtained; but even there they were far from abundant. They consist essentially of land shells; the two exceptions are so rare that they only prove the rule; for *Planorbis albus*, which lives on water-plants and frequents marshes, can pass over land surfaces, while the *Limnæa truncatula* "is nearly amphibious, being more frequently met with out of the water than in it; it is also found in very elevated spots"*. Dr. Gwyn Jeffreys, who has kindly examined the collection, tells me that the species present no peculiar variations.

The following are the species found in bed *b*. In order to show their relative abundance, I have given the total number obtained during some days' search:—

	No. of specimens.		No. of specimens.
Pupa marginata, *Drap.*	226	Succinea oblonga, *Drap.*	11
Helix hispida, *Linn.*	53	Limnæa truncatula, *Müll.*	3
Limax agrestis, *Linn.*	1	Planorbis albus, *Müll.* (young)...	1

I met with no fragments of wood, except one derived probably from Tertiary strata.

A short distance further the chalk rose rather abruptly to the surface; but the drift reappeared a quarter of a mile further on, occupying a small shallow hollow, in which it presented no new features, and where no organic remains were met with. As a whole, the drift becomes coarser and more flinty as it trends to this end.

The level of the base of this drift at its northern extremity is 290 feet, and of its top at its southern end 407 feet above the sea-level,—the level of the Thames at its nearest point (Moulsford) being about 140 feet, and that of the Gault plain below Didcot about 160 feet above the sea-level.

* Jeffreys, 'British Conchology,' vol. i. p. 83.

The peculiar features of this Drift are the absence of worn débris indicating prolonged water-action, and of either marine or fluviatile remains; the presence, it may be said, exclusively of the remains of a land-fauna; its high position of 150 to 260 feet above the adjacent river-level; the irregularity of its bedding; and its wide spread, westward towards Hendred, over the adjacent plain. Sections of it are to be seen in places near a pond and in a shallow excavation two miles distant from the cutting; but there are no deep sections.

The only analogous beds to which I can refer this Drift are the heads of angular rubble overlying the Raised Beaches of Sangatte and Brighton. In all three we find similar mammalian remains, the same irregularity of bedding, and the same absence of wear in the component materials; and at Sangatte I found the same land-shells. The only difference is that the Sangatte and Brighton drifts are more flinty and coarser; but that is a feature merely dependent on the circumstance that at both these places the adjacent chalk is the Chalk-with-flints, whereas at Chilton it is the Lower Chalk.

It is a Drift not following any river-course; nor is it a marine Drift, nor a glacial Drift from the northward; but the constituent parts are either all *local*, or else derived from strata immediately southward—that is to say, from the Upper Chalk-with-flints, and from the Lower Tertiary strata which cap the Chalk hills between Ilsley and Newbury. For besides the glauconite grains which, though probably from the Lower Tertiaries, may be also from the Upper Greensand, we have the more certain Tertiary sandstone blocks (Sarsen stones); while from the Upper Chalk we not only have the flints from the Chalk hills of East Ilsley, but abundant harder fragments of the limestone-chalk derived from the thin bed (two to five feet) of chalk-rock lying between the Lower and the Upper Chalk, and which crops out on the slope of the great chalk escarpment one mile to the south of the Chilton cutting.

This Drift is therefore analogous to the great Land-wash or diluvial deposit which I have described as overlying the Raised Beaches on our southern coast and on the opposite coast of France; only here it is inland, and is the only inland case of a Drift so closely resembling the drifts of Brighton and Sangatte that I have met with in the South of England*.

It appears to fill hollows on this elevated chalk plain in a manner rather difficult to account for. The hollows may have been the deep dry combes so common amongst chalk hills, of which the drift has filled up the irregularities and spread also over portions of the adjacent surface. Further, I think it is to the same action that we must ascribe the trail of Sarsen stones which are scattered lower down over the valley of soft Upper Greensand. Although so many

* There are, however, others, though differently constituted, which I mentioned in a paper read at the last meeting of the British Association at Swansea, but as yet only published in abstract.

of these blocks have been broken up and removed, they are still numerous in and around the villages of Upton, East and West Hagbourne, and in other valleys below the line of the chalk escarpment.

There was an entire absence of the oolitic débris and of the quartzite pebbles which formed so large a proportion of the old valley- or river-gravels.

To show the relation which this angular drift bears to the subangular river-valley gravels, I have given a general section of the country from Culham Station to the summit of the upper chalk escarpment near East Ilsley (fig. 2). The independence of the two drifts will be apparent from this section. In the Thames valley, and at levels of from 10 to 20 feet above the river, a large number of mammalian remains have been found, including specimens of *Elephas primigenius*, *E. antiquus*, *Hippopotamus major*, *Rhinoceros tichorhinus*, *Equus fossilis*, *Bos primigenius*, *Cervus elaphus*, and *C. capreolus*, together with species of freshwater shells of the genera *Pisidium*, *Valvata*, *Ancylus*, &c., and, lastly, *Cyrena fluminalis*, in the old river-gravel.

In the section fig. 1, point a' represents a deposit of "rain-wash" filling a depression some 200 feet in length by 10 feet deep in the centre. It is roughly stratified, consists of a brown clay with carbonaceous bands, and abounds with well-preserved specimens of *Cyclostoma elegans* and *Helix nemoralis*.

In conclusion, I have to express my obligation to the resident engineer, Thomas Scott, Esq., for the levels and a tracing of the cutting.

Discussion.

The President remarked upon the value of this paper as calling attention to a very peculiar form of drift, and inquired if beneath the datum-lines of the railway there were indications of a further extension of this peculiar drift. The occurrence of mammalian bones in so dry a situation was peculiar.

Prof. Hughes said that he had received a few specimens, chiefly of antiquities, from this district, from the Rector of Upton. It appeared to him that there was a kind of rainwash, or subaerial débris, washed into a hollow at the time when the Mammoth lived, and a small pond had at one time been formed in the hollow. One point of interest was the relation of this deposit to the more northern glacial deposits; it was remarkable that there were no fragments whatever, such as were commonly found in the postglacial drifts further north. Did this belong to the period of extreme cold, or of heavy flushes of rain-water at a later time?

Mr. Tiddeman suggested that some other sections of a similar character existed, as on the east flank of the Malvern hills, where was an angular unworn deposit formed of the débris of the hill, and lying at a very low gradient. This, as he was informed by the Rev.

W. S. Symonds, overlay at Malvern remains of *El. antiquus*, *Rh. leptorhinus*, &c. As these remains lay *under* glacial drift at Settle and Raygill, in West Yorkshire, and there was much evidence that the Mammoth fauna survived to a later period than *El. antiquus* and its companions, he thought that the facts pointed to the probability of the beds containing Mammoth and Reindeer, described by Prof. Prestwich, having been formed during a time of heavy and frequent snows, whilst the north-west of England was undergoing glaciation.

Prof. Prestwich in reply described the general section of the neighbourhood; in the lower ground were drifts which contained foreign pebbles, but not so in this upper drift. Whatever was in it had come from the hills above it. He did not think it was rain-wash; it was too coarse and on too gentle a slope for that; a true rain-wash did occur here of quite a different character.

14. Description *of some* Iguanodon-remains *indicating a new Species*, I. Seelyi. By J. W. Hulke, Esq., F.R.S., Pres. G.S. (Read February 8, 1882.)

[Plate IV.]

Although a very large number of *Iguanodon*-remains are now to be found in the public and private collections in this country, they consist, for the most part, of dissociated bones. Discoveries of several bones of this Dinosaur under such circumstances as warrant the belief that they formed part of one skeleton have been extremely rare, on which account our knowledge of the proportions of the several parts of the skeleton has remained very incomplete.

The announcement of the discovery of a very large series of Iguanodon fossils at Bernissart in 1878 raised the expectation that before long a complete osteology of *Iguanodon* would issue under the auspices of the Belgian government. An examination of some of these remarkable fossils, which the obliging director of the Musée d'Histoire Naturelle at Brussels allowed me to make in Aug. 1879, showed me that their importance had not been exaggerated, and it led me to defer the completion of this communication, which I had begun some time before. Having, however, recently been told by M. Boulenger, to whom their description is intrusted, that no exhaustive memoir on them is to be expected for several years, I no longer hesitate to present to the Society an account of some fossils obtained by myself in the Isle of Wight in 1870, which afford, in particular, very considerable information respecting the form and proportions of the several members of the hind limb.

These remains comprise the nearly complete right hind limb and the right humerus, the left haunch-bone, and the left foot, three caudal vertebræ, and several chevrons.

All these fossils, with the exception of the humerus and vertebræ (which occurred at the distance of a few feet east of the others in the same bed), were lying in a small area of a few square yards, in a bed of hard nodules intercalated between the red and purple clays below and the iron-stained flint-gravel which caps the cliff west of Brook Chine. This nodule-bed has an apparent westerly dip; it soon crosses the shore, where it is usually hidden by sand and seaweed; and it then passes out seawards under the well known Pine Raft. A few yards east of where this nodule-bed touches the cliff-foot, the cliff is cut through by a small gully worn by a little rill. In the east bank of this gully were the fossils.

The coxswain of the lifeboat told me that, about ten years before, he saw a gentleman take out of the same spot nearly a cart-load of bones. I have not been able to ascertain the name of this fortunate discoverer, or the present locality of these fossils.

Ilium (Pl. IV. fig. 1).—The present length of this large and massive bone is 118 centim. (47 in.)*; but as a small piece is broken off at each end, its length when perfect was probably not less than 124

* The reduction to English measure throughout is only approximate.

Fig. 1.—*Restoration of the Left Hind Limb of* Iguanodon Seelyi. (About $\frac{1}{20}$ nat. size.)

centim. (about 4 feet). Its greatest depth, from the dorsal to the ventral border behind the acetabulum through the ischial process, is 33 centim (13 in.). The dorsal border viewed from above is sinuous; it bends outwards above the ischial process, and again in the preacetabular process. In a side view it is seen to rise slightly from the last-named process to above the ischial process, its highest point, whence it slopes uniformly downwards to the posterior end of the bone. The ventral border behind the acetabulum is straight; it is longitudinally grooved. The preacetabular process (*pa*) is relatively short, its length being less than that of the postacetabular part of the bone; it contracts rapidly from its stout base, and for more than half its length it is much flattened. Its cross-section at 10 centim. (4 in.) from its free end is an oval figure the diameters of which are $3\frac{2}{5}$ centim. ($1\frac{1}{5}$ in.) and 11 centim. ($4\frac{1}{3}$ in.). The chord of the acetabular arc is 23 centim. (9 in.). The pubic process (*p*) is angular; it juts downwards and forwards. The ischial process (*i*) is a stout low swelling. The outer surface of the ilium is

relatively even. The inner surface is stamped with a chain of impressions overhung by a projecting ledge, marking the attachment of the sacrum.

The elongated figure of the ilium places the animal represented by it beyond doubt in the family Iguanodontidæ. In the comparative shortness and stoutness of the preacetabular process and the more tapering form of the postacetabular front of the bone, this ilium certainly differs from that of *I. Mantelli*, regarding as the type of this latter the ilia preserved in the large slab from Bensted quarry in the British Museum, which originally formed part of the collection of the late Dr. G. A. Mantell.

Femur (Pl. IV. fig. 2).—The proximal end of this gigantic bone is crushed; but the distal end is fairly preserved. The present length of the femur is 92 centim. (3 feet); when entire the length was probably not less than 108 centim. ($42\frac{1}{2}$ in.). The distal end has the usual condylar division; the condyles project strongly backwards. The anterior intercondylar groove (*ic*) is characteristically deep and narrow. The shaft has an apparent twist, owing to a change in the direction of its surface; that which at the proximal end is external becomes towards the distal end anterior or dorsal. The inner trochanter (*i t*) is strongly marked. The girth of the femur at the distal condylar end is 82 centim. ($32\frac{1}{4}$ in.), and the breadth across the condyles is 32 centim. ($12\frac{3}{5}$ in.). The girth of the shaft just above the condyles is 69 centim. (27 in.), and that immediately above the inner trochanter is 64 centim. ($25\frac{1}{5}$ in.). Towards the proximal end the girth again increases. These measurements will furnish an idea of the size and proportions of this thigh-bone, which is one of the very largest I have yet seen.

Tibia (Pl. IV. fig. 3).—I found this lying athwart the thigh-bone. Both its ends are much crushed and mutilated. The precnemial crest was very large; it was so shattered that in spite of great care it fell to pieces as we lifted the bone out of the cliff, and it could not be restored. The shaft has the usual subprismatic figure in its central part, and it expands towards its articular extremities. The breadth of the lower end, approximately inferred from that of the composite articular surface formed by the proximal end of the metatarsal bones, will not have been less than 35 centim. (nearly 14 in.); the proximal end still shows, obscurely, a subdivision into two parts corresponding to the femoral condyles. The length of the tibia in the present mutilated state is 92 centim. (36 in.); 102 centim. (40 in.), somewhat less than that of the femur, will not, I think, be an unfair estimate of its length when perfect. The girth at the middle of the shaft is 45 centim. ($17\frac{7}{10}$ in.).

Fibula (Pl. IV. fig. 4).—This bone, nearly as long as the tibia when perfect, has been shortened to 85 centim. ($32\frac{1}{2}$ in.) by mutilation of its distal end. The proximal end is broad and flattened; the tibial aspect is slightly hollowed. The shaft is relatively slender; its figure is subprismatic. (The *os calcis* and *astragalus* were not recovered.)

Foot (Pl. IV. fig. 5).—The bones of the left metatarsus, cemented together by rock, preserve their natural relations but slightly disor-

dered. Those of the right metatarsus had fallen apart, but were lying by one another. Both metatarsi demonstrate conclusively that the hind foot in *Iguanodon* has three, and only three, functional toes, the number actually present in the hind foot of an immature Iguanodon in Mr. S. H. Beckles's collection, several years since described and figured by Prof. Owen, in his 'Fossil Reptilia of the Wealden Formations.'

Of the three metatarsals the inner is shortest, being 26 centim. ($10\frac{1}{4}$ in.) long. Its proximal end is much extended in the dorso-plantar direction, this diameter measuring 21·3 centim. ($8\frac{2}{5}$ in.), whilst the transverse or horizontal diameter is but 10·2 centim. (4 in.). The distal end, condylarly divided, is asymmetrical, the outer condyle being narrower and slightly deeper than the inner, than which it also diverges more from the axis of the bone. The intercondylar groove scarcely rises above the middle of the articular surface. The inner surface of the metatarsal (that which looks towards the middle metatarsal bone) is flattened; and its junction with the dorsal or upper surface in the distal half of the bone projects in the form of a thin overhanging lip, by which it may be distinguished from the outer metatarsal. This process is not peculiar to *Iguanodon*; for it is distinctly represented in a metatarsal of *Poikilopleuron Bucklandi*, figured by E. Deslongchamps, père, also in Prof. Cope's figures of a metatarsal of *Hadrosaurus Foulkii*, and it is present in the innermost metatarsal of *Hypsilophodon Foxii*.

The middle metatarsal bone is 35·5 centim. (14 in.) long. The shape and proportions of its proximal end, now distorted, do not appear to have differed much from those of the inner metatarsal. The dorsal border of this end is produced upwards in the form of a lip adapted to the pulley-groove of the conjoined astragalo-calcaneum. The distal condyles are nearly symmetrical. The intercondylar groove rises higher than in the other metatarsals. The breadth across the condyles is 14 centim. ($5\frac{1}{2}$ in.); that of the middle of the shaft is 10·5 centim. ($4\frac{1}{8}$ in.), the vertical diameter at this part being 6·4 centim. ($2\frac{1}{2}$ in.).

The outer metatarsal is 29 centim. ($11\frac{2}{5}$ in.) long; its length is therefore intermediate between those of the other two metatarsals. The proximal end is concave vertically and slightly so horizontally, its figure being the counterpart of the corresponding articular surface of the calcaneum. The distal condyles are asymmetrical; the outer, that furthest from the middle line of the foot, is narrower, deeper, and more divergent from the axis of the bone than is the inner condyle. The breadth across the condyles is 12·6 centim. (5 in.); and that of the proximal end is 15 centim. ($5\frac{9}{10}$ in.).

It has been already stated that neither of these metatarsi lends any support to the idea that the hind foot in *Iguanodon* had more than three functional toes. A fragment cemented by rock to the basal end of the inner metatarsal in the left metatarsus perhaps represents the rudiment of a fourth metatarsal preserved in Mr. Beckles's fossil, to which reference was lately made. The alternative of its being a piece of a chevron is suggested by the agglutination of two chevrons to the plantar surface of the metatarsus.

Phalanges.—With the exception of one proximal phalanx referable

to the right foot, which was found lying apart from the others, all the phalanges were found in three groups, each representing a toe of the left foot. Reconstructed on the type of the hind foot in *Hypsilophodon Foxii*, the outer toe has five, the middle four, and the inner toe three phalanges, the number assigned by Prof. Owen to these toes in his restoration of Mr. Beckles's specimen; these toes are therefore homologous with the three outer functional toes in *Hypsilophodon*, and with the 2nd, 3rd, and 4th toes of extant lizards.

Taking, for convenience of description, the toes in order from the inner to the outer side of the foot, the proximal phalanx of the inner toe is stout, and nearly as long as the corresponding phalanx of the middle toe, than which, however, it is more slender and constricted at the middle. The proximal end, now nearly flat, was doubtless, in the fresh state, adapted by a cartilaginous lip for the reception of the metatarsal condyles. The contour of this end is rudely trigonal, the apex directed outwards, the base towards the middle toe. The distal end of this as of all the other phalanges is condylarly divided. On the outer border of the phalanx, nearer to the proximal than to the distal end, is a swelling suggestive of the attachment of a strong tendon. The length of this phalanx between its extreme points is 15 centim. ($5\frac{9}{10}$ in.); the girth of the proximal end is 38 centim. (15 in.), that of the distal end 36 centim. ($14\frac{1}{5}$ in.), and that of the middle of the phalanx is 37 centim. ($14\frac{1}{2}$ in.). The horizontal diameter of the proximal end is 12·6 centim. (5 in.), and the vertical diameter 10·8 centim. ($4\frac{1}{4}$ in.). The breadth across the condyles is 11·5 centim. ($4\frac{1}{2}$ in.). The second phalanx of this toe, measured along its dorsal surface, is 6 centim. ($2\frac{1}{3}$ in.) long, less than half the length of the first phalanx; this surface is produced backwards in the form of a lip adapted to the intercondylar groove of the distal end of the first phalanx. The outline of the proximal end is triangular; the articular surface is concave in the vertical direction, and sinuous in the horizontal. The distal end is pulley-shaped; its articular surface is prolonged backwards along the plantar aspect of the bone, so as nearly to meet the proximal articular surface. The horizontal diameter of this phalanx is 9·5 centim. ($3\frac{3}{4}$ in.), and the vertical diameter 7·2 centim. ($2\frac{4}{5}$ in.). The third or ungual phalanx is only inferior in size to that of the middle toe. It is broad, blunt, and curved slightly downwards—a form adapted to grubbing. Its extreme length is 17 centim. ($6\frac{7}{10}$ in.). At about 4 centim. ($1\frac{3}{5}$ in.) from the proximal end its lateral borders project in a lip-like form, within which is a conspicuous submarginal nail-groove. The dorsal surface of the phalanx is convex longitudinally and transversely; the plantar surface is concave longitudinally, and slightly convex transversely. The vertical and horizontal diameters of the proximal end are each 7 centim. ($2\frac{3}{4}$ in.). The transverse, horizontal diameter at the base of the nail-groove is 10·1 centim. (4 in.), from which part the breadth contracts to 6·3 centim. ($2\frac{1}{2}$ in.) at the distance of 2 centim. ($\frac{4}{5}$ in.) from the distal end.

The middle, or second toe, had four phalanges, of which the second or antepenultimate was unfortunately not recovered. Unrecognized at the moment by the labourers who worked under my guidance, it was

probably thrown down the cliff with the rubbish; and later, when missed, it could not be found. The proximal phalanx is remarkably stout. Its extreme length is 13 centim. ($5\frac{1}{10}$ in.). The horizontal diameter of its proximal end is 14·1 centim. ($5\frac{1}{2}$ in.), and the vertical diameter 10·1 centim. (4 in.). The breadth across the condyles is 12·6 centim. (5 in.), and the vertical diameter at the intercondylar groove 7·5 centim. (3 in.). The vertical diameter at the middle of the phalanx is 7·3 centim. ($2\frac{9}{10}$ in.), the horizontal diameter 10·5 centim. ($4\frac{1}{8}$ in.). From these dimensions it will be seen that the figure of this phalanx is short, stout, somewhat flattened, and slightly contracted at the middle. The third phalanx is very short, only 4·2 centim. ($1\frac{3}{5}$ in.) long, measured along the upper surface. Its shape is rudely triangular. The vertical diameter of the proximal articular surface is 8·3 centim. ($3\frac{1}{4}$ in.), the horizontal 12·3 centim. ($4\frac{4}{5}$ in.). This surface is concave vertically and sinuous transversely. The dorsal surface in this as in all the other short phalanges is prolonged backwards in a lip-like form, adapted to the pulley-like articular surface of the phalanx behind it; and the distal articular surface, which has the form of a wide shallow pulley, is, as in the other short phalanges, prolonged on the plantar aspect nearly to the proximal surface of the bone. The terminal or ungual phalanx of this toe may be distinguished from that of the other toes by its symmetry. Its extreme length is 17·6 centim. ($6\frac{9}{10}$ in.). The horizontal diameter of the proximal end is 9 centim. ($3\frac{1}{2}$ in.), and the vertical diameter about 7 centim. ($2\frac{3}{4}$ in.). The articular surface is sinuous horizontally and concave vertically. The transverse or horizontal diameter at the base of the nail-groove is 11·2 centim. ($4\frac{2}{5}$ in.), and at the distance of 2 centim. ($\frac{3}{4}$ in.) from its distal end 6 centim. ($2\frac{1}{3}$ in.).

The third or outer toe has five phalanges. The proximal of these resembles that of the middle toe more than that of the outer toe; but it is shorter and, relatively to its length, it is stouter than the former. The horizontal diameter of its proximal end is 12·2 centim. ($4\frac{4}{5}$ in.), the vertical is 10 centim. ($3\frac{9}{10}$ in.). The same diameters of the distal end are 10·2 centim. ($4\frac{4}{5}$ in.), and 7·6 centim. (3 in.). The breadth of this phalanx at its middle is 8·6 centim. ($3\frac{2}{5}$ in.). The lateral mesial surface is flattened. The three succeeding phalanges resemble one another so closely as not to require separate descriptions. They resemble those phalanges which in the other toes are intermediate between the proximal and the ungual, and differ from these chiefly in their proportions, as may be seen by the following measurements :—

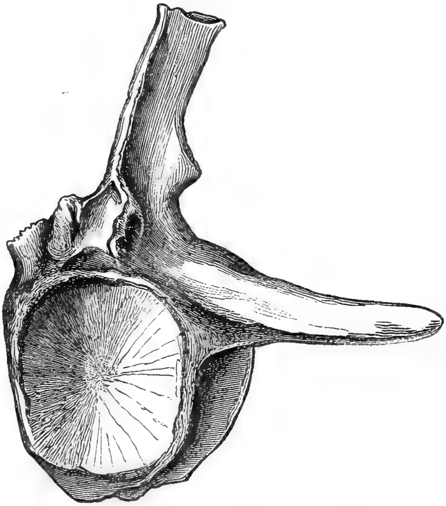
	2nd phal. centim.	3rd phal. centim.	4th. phal. centim.
Length along dorsal surface	4 ($1\frac{3}{5}$ in.)	3·5 ($1\frac{2}{5}$ in.)	2·3 ($\frac{9}{10}$ in.)
Horizontal transverse diameter	9·7 ($3\frac{4}{5}$ in.)	9·3 ($3\frac{2}{3}$ in.)	8·4 ($3\frac{1}{3}$ in.)
Vertical transverse diameter	8·4 ($3\frac{1}{3}$ in.)	6·1 ($2\frac{2}{5}$ in.)	6·2 ($2\frac{1}{2}\frac{1}{8}$ in.)

All the three phalanges are therefore very short relatively to their horizontal diameter or breadth. In all, the dorsal surface sends

backwards a lip adapted to the intercondylar groove of the phalanx next behind; and the under surface is reduced to a minimum by the plantar prolongation backwards of the distal articular surface. The ungual phalanx of this toe is smaller than that of the other toes. Its figure is less symmetrical than that of the middle toe. An outward inclination serves to distinguish it from the claw-bone of the inner toe, than which it is also less blunt. Its present length is 14 centim. ($5\frac{1}{2}$ in.); but when perfect it was probably not less than 15·5 centim. (6 in.) long. The vertical diameter of its proximal end is 6·1 centim. ($2\frac{2}{5}$ in.), and the horizontal diameter 5·7 centim. ($2\frac{1}{4}$ in.). The breadth of the phalanx at the base of the claw-groove is 8·3 centim. ($3\frac{1}{4}$ in.), and at 2 centim. ($\frac{3}{4}$ in.) from the distal end it is 4·2 centim. ($1\frac{2}{3}$ in.).

Vertebræ (fig. 2).—The three caudal vertebræ were found cemented together by rock, which has preserved their natural sequence. A slight lateral dislocation has permitted me to lay bare their articular surfaces. The centra are short; measured along the neural surface their length is only 11·4 centim., 11 centim., and 10·6 centim. ($4\frac{1}{2}$, $4\frac{1}{3}$, and $4\frac{1}{6}$ in.). The vertical dimension, or height, measured from the neural surface to the under surface between the chevron-facets, is 18·6 centim., 18·4 centim., and 17 centim. ($7\frac{1}{4}$, $7\frac{1}{3}$, and $7\frac{1}{10}$ in.). The horizontal diameter below the root of the transverse process is 13·2 centim., 13·4 centim., and 12·3 centim. ($5\frac{1}{5}$, $5\frac{1}{4}$, and $4\frac{4}{5}$ in.).

Fig. 2.—*Oblique anterior View of an early Caudal Vertebra of* Iguanodon Seelyi. (About $\frac{1}{7}$ nat. size.)



A gentle expansion of the centrum towards its articular ends imparts to the lateral surfaces a slight concavity in the antero-posterior direction. These surfaces are nearly plane in the vertical direction; and below they converge slightly. The under surface is much reduced by the encroachment of the chevron-facets, of which the posterior is much the larger. The great size of these facets diminishes the lateral surfaces in the lower third of their extent;

and it also obliquely cuts off the lower part of the terminal articular surfaces, which gives to these a very square contour. The articular surfaces are both concave, the anterior very slightly so, the posterior very decidedly. In the latter surface (in the third centrum of the series) the bottom of the concavity lies 1·6 centim. ($\frac{3}{5}$ in.) in front of a plane laid through the circumference. The horizontal diameter of this surface, below the level of the transverse process, is 13·7 centim. ($5\frac{2}{5}$ in.), which is reduced to 12·7 centim. (5 in.) at its lowest limit, where it is cut off by the chevron-facet. The vertical diameter of the surface is equal to the side of the square, 11·7 centim. ($4\frac{3}{5}$ in.).

The neural canal was very small: the transverse measurement of its floor is under 3 centim. ($1\frac{1}{5}$ in.); and its height is less. The neurapophyses are stout; their attachment to the centrum is nearly coequal with the antero-posterior extent of this latter. The neural spines, strong flattened blades, having an antero-posterior expansion of 7·5 centim. (3 in.), rake backwards, and form with a plane through the neural surface of the centrum an angle of about 125°. Their length was plainly considerable: that of the best-preserved one is 19 centim. ($7\frac{1}{2}$ in.); and it has evidently been broken at some distance from its true end.

A long and stout transverse process stands off from the junction of the lateral and upper surfaces of the centrum. It is a horizontally flattened blade with a slight backward curve. Its average width is 6 centim. ($2\frac{1}{3}$ in.). The vertical diameter of the process near its root is 3 centim. ($1\frac{1}{5}$ in.), which is reduced to 1·4 centim. at the distance of 15 centim. ($5\frac{9}{10}$ in.). Its length when entire was probably not much more.

Relatively to the great bulk of the vertebræ the zygapophyses are small; the front pair project forwards and slightly outwards directly above the crown of the arch; their articular surfaces look inwards and slightly forwards. The postzygapophyses have an oval articular surface 4 centim. by 3 centim. ($1\frac{3}{5}$ by $1\frac{1}{5}$ in.).

Dislocated, but cemented to the centrum by rock, are parts of three chevron bones. In two of these, the basal end which articulated with the vertebral centrum is well preserved. It consists of two crescentic parts, of which the anterior is the larger, meeting angularly. A depression in the anterior division received a corresponding swelling in the posterior facet of the vertebral centrum when the chevrons were articulated. The forked portion of the chevrons is 12·5 centim. ($4\frac{9}{10}$ in.) long. The undivided blade, when entire, certainly much exceeded this; and I think it not improbable that the length of an entire chevron attained 45 centim. ($17\frac{3}{4}$ in.). Other detached chevron bones have nearly the above dimensions.

In their transverse processes and chevrons we have the clue to the place of these vertebræ in the tail.

Other remains referable to *I. Mantelli* obtained by me in the same locality afford evidence that the foremost chevron bone is intercalated between the second and third caudal vertebræ, and that the second centrum has but one chevron-facet, from which it is apparent that the three vertebræ just described occurred later in the series. In *I. Mantelli*, as in *Hypsilophodon Foxii*, the transverse processes of the

first three caudal vertebræ are dwarfed; and they disappear at about the tenth centrum reckoned from the sacrum. The length of their transverse processes leads me therefore to place the three vertebræ between the fourth and ninth in the postsacral chain. Their strong resemblance to the vertebræ referred by Dr. G. A. Mantell and Prof. R. Owen to *Pelorosaurus* is very suggestive of the identity of this with my Brook Iguanodon.

Humerus (Pl. IV. fig. 6).—With the exception of the distal end, which has been crushed off, this bone is excellently preserved. Its present length is 67 centim. ($26\frac{2}{5}$ in.); 10 centim. would not be an excessive allowance for the missing part, which would make the original length 77 centim. (30 in.); but it should be understood that this is only an approximation.

The proximal half of the bone is compressed. The ventral surface of this part is hollow transversely; and the dorsal surface is convex in the same direction. The proximal end is convex; the articular surface (*p a*) is at the summit of the curve. From it is produced upon the dorsal surface of the bone, to a distance of 15 centim. ($5\frac{9}{10}$ in.), a stout, rough ridge, bounded on each side by a wide shallow groove. The posterior border of the bone is concave; and at its junction with the proximal end is an angular backward projecting process (*p p*), as in the humerus of *I. Prestwichii.*

A strong rough crest gives a convex contour to the anterior or radial border of the bone. This crest, which begins at the proximal end, subsides at the distance of 38 centim. (15 in.) from it. The broad hollow noticed in the ventral surface of the proximal end is continued down the shaft in the form of a wide shallow groove, which only disappears where the shaft begins to expand near the distal condyles. The dorsal aspect of the shaft is convex transversely. This configuration of the dorsal and ventral surfaces gives to a cross section of the shaft an oval shape, in which the curve answering to the ventral surface is indented at its middle. The chord of the proximal end is 26·5 centim. ($10\frac{2}{5}$ in.). The breadth of the bone at the most salient part of the radial crest is 21·5 centim. ($8\frac{1}{2}$ in.); and the girth of the shaft is 40 centim. ($15\frac{3}{4}$ in.).

It will be seen that the form of the proximal end of this humerus agrees with that of *I. Prestwichii* *, and differs greatly from the representations of a humerus in the collection of J. B. Holmes, Esq., of Horsham, given by Prof. R. Owen in his 'Fossil Reptilia of the Wealden Formations,' pl. xiv. figs. 3, 4. These figures I never understood until, some time since, by the courtesy of Mr. Holmes, I had an opportunity of examining the specimen. Its proximal end is, in great part, a restoration in Roman cement, and "pl. xiv. figs. 4, 5. Monograph Iguanodon" are, I was informed by Mr. Holmes, copies of drawings by Miss Holmes. To the great artistic talent of this lady, her very beautifully executed and truthful drawings of fossil bones which I have seen bear testimony. I shall, however, not do her any injustice if I suggest the absence of such critical anatomical knowledge as would have enabled her to distinguish the real from the fictile parts of the bone.

Dermal Covering.—I had long possessed evidence that *Iguanodon*

* Quart. Journ. Geol. Soc. vol. xxxvi. p. 454.

had a scuted hide; but until the acquisition of these remains such evidence was very fragmentary. In cutting away the rock from the larger bones of the hind limb, I found beneath it a layer of bony tissue separated from the endoskeleton by a deeper layer of rock enclosing much black carbonaceous matter. From its position with reference to the endoskeleton it was obvious that the outer layer of bony tissue was exoskeletal—was in short a dermal mail. In order to lay bare the tibia, it was necessary to cut away a greave of such dermal covering. The scutes composing it are distinctly bony, of irregular polygonal form; some are 2 centim. ($\frac{4}{5}$ in.) thick, and 7 centim. ($2\frac{3}{4}$ in.) in diameter. Their external surface is slightly pitted.

For the *Iguanodon* indicated by these remains, the distinctness of which from those of *I. Mantelli* * is beyond doubt, I propose the specific name *Seelyi* (*Iguanodon Seelyi*), in slight acknowledgment of the great courtesy of Charles Seely, Esq., of Brook House, in permitting me to excavate the cliff for their recovery.

EXPANATION OF PLATE IV.

Fig. 1. The left ilium, outer view: *p*, the pubic process; *i*, the ischial process; *pa*, the præacetabular process. $\times \frac{1}{8}$.
2. The right femur, dorsal or anterior view: *ic*, the deep anterior intercondylar groove; *i t*, the inner trochanter. $\times \frac{1}{8}$.
3. The right tibia, anterior view. $\times \frac{1}{8}$.
4. The fibula, outer view. $\times \frac{1}{8}$.
5. The left foot: *m*, metatarsus; ii, the inner; iii, the middle; iv, the outer toe. $\times \frac{1}{8}$.
6. The right humerus, dorsal view: *p a*. proximal articular surface; ***p p***, the posterior process; *r*, the radial crest. $\times \frac{1}{8}$.

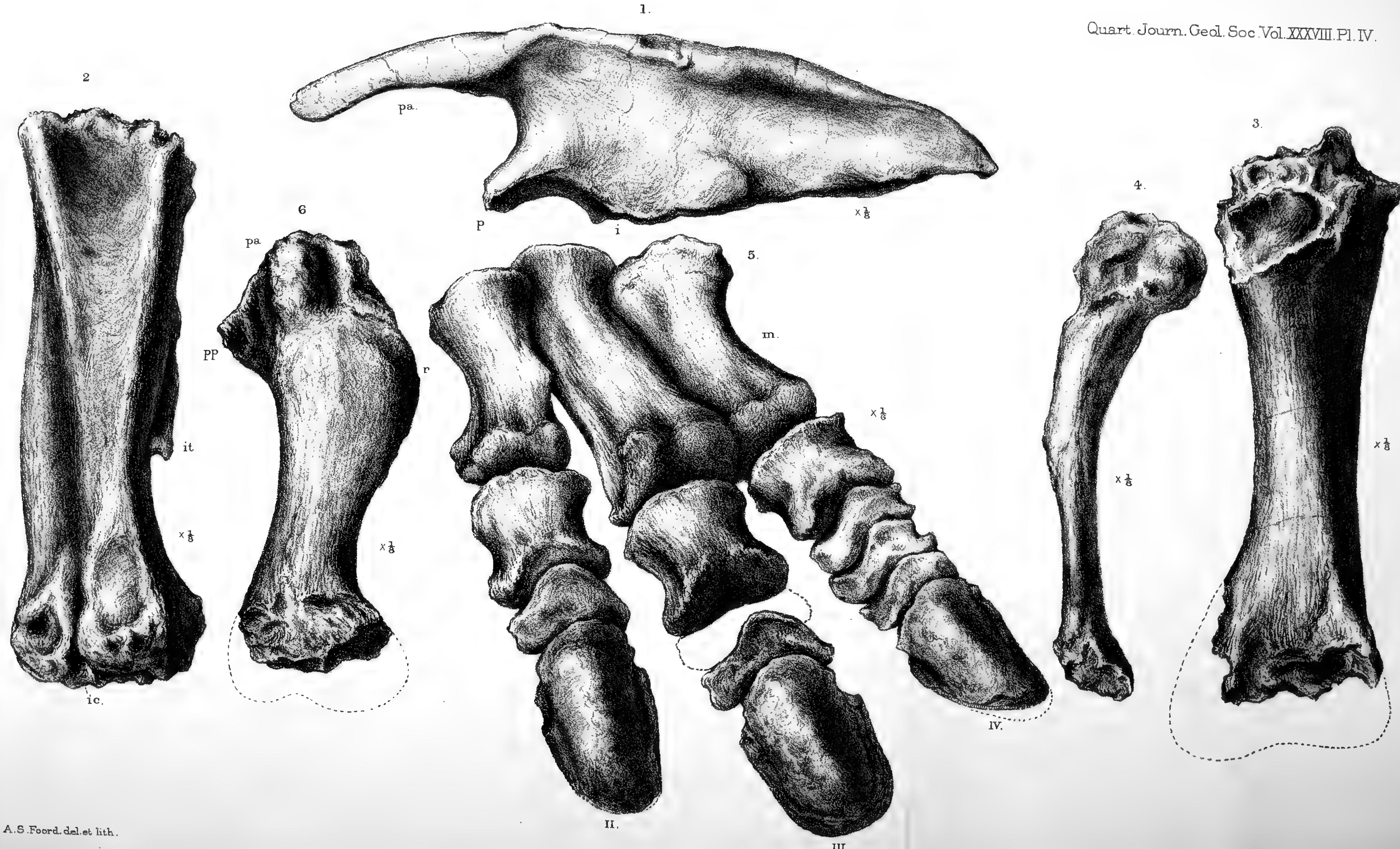
DISCUSSION.

Prof. SEELEY spoke of the important work carried on by the author, whereby genera founded on imperfect evidence had been got rid of. He doubted whether a form with an ilium so different from that of *Iguanodon Mantelli* ought to be referred to the same genus. The same doubts were suggested by the different proportions of the limb-bones, and by peculiarities of the vertebræ, as compared with those of *Iguanodon*.

Dr. MURIE thought that the foot might have been slightly webbed, and remarked that the hind limb was remarkably bird-like, as shown by the diagram; but he doubted whether the natural position of the limb-bones was that represented by the author in his restoration. He thought that the bones called by the author chevron bones in the foot might be sesamoid bones. He believed with the author that the tail was mailed.

Mr. HULKE said that he could not entertain the idea that the chevron bones on the foot could be regarded as sesamoid bones. True sesamoid bones were, indeed, present; but portions of chevron bones had been accidentally fossilized in connexion with the foot. None of the footprints showed any trace of a web. He agreed with Prof. Seeley as to the great size of the tail. With the present evidence he thought it safer to refer the form to *Iguanodon* than to create a new genus.

* The Iguanodon indicated by the remains in the well-known slab figured in the Foss. Rept. of the Cretaceous formations, pls. xxiii. xxiv., is taken as the type of *I. Mantelli*.



A. S. Foord. del. et lith.

IGUANODON SEELYI.

Mintern Bros. imp.

15. *On the* Crag Shells *of* Aberdeenshire *and the* Gravel-beds *containing them.* By Thomas F. Jamieson, Esq., F.G.S. (Read March 8, 1882.)

Contents.

Introductory.
Extent and Distribution of the Gravel.
Internal Structure and Contents of the Gravel Ridges.
The Coast Section.
Order of Succession and Derivation of the Beds.
List of Shells, with Remarks on the Species.
Details of a few Sections along the Coast of Slains.

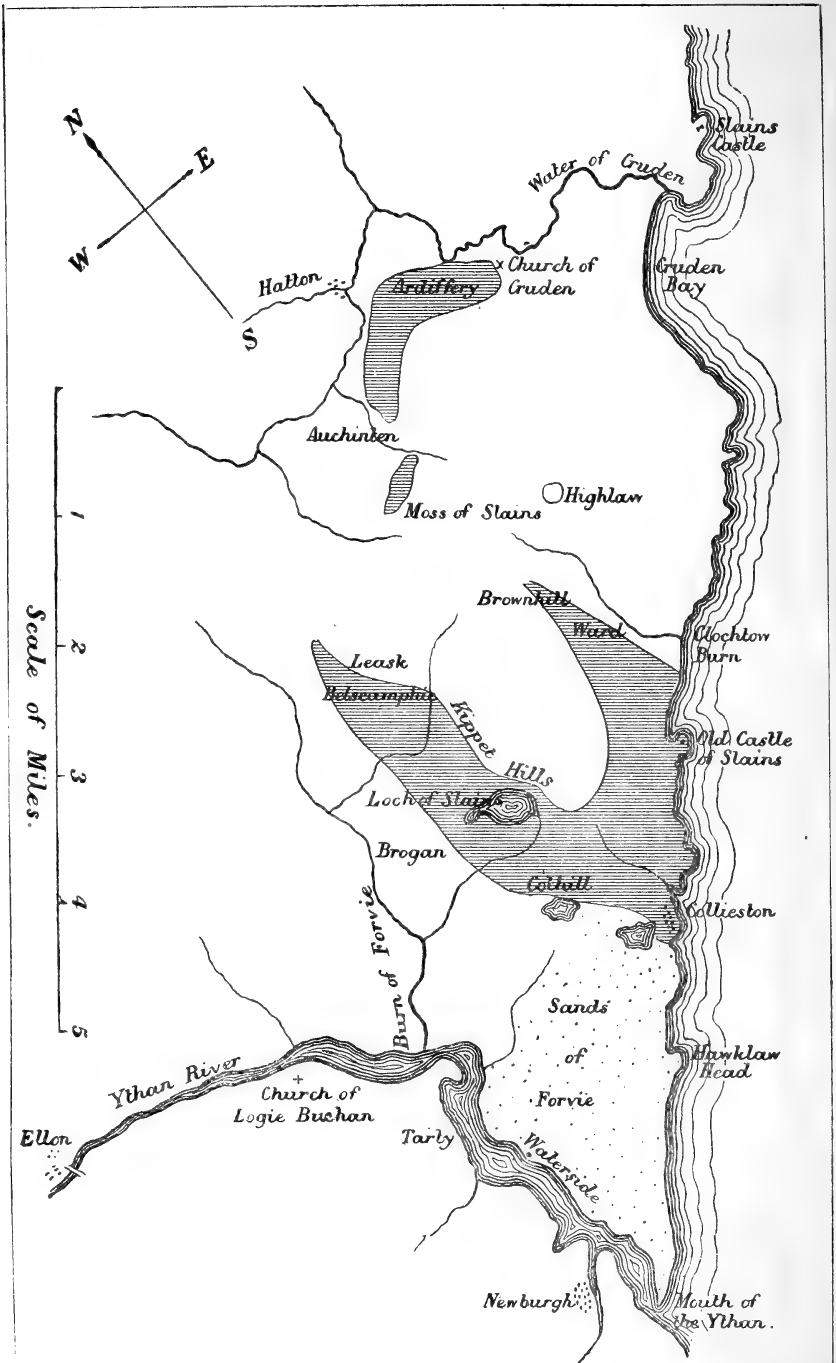
In the year 1860 I sent to the Geological Society a short notice of certain beds of sand and gravel on the eastern border of Aberdeenshire, which I had found to contain fragments of shells resembling those met with in the Crag strata of Norfolk. These shells are much broken and worn—most of them mere crumbs; and few are in a condition to enable even a skilful conchologist to pronounce with certainty as to their specific character, although it is sufficiently clear that they represent a considerable variety of forms. Nevertheless characteristic specimens distinct enough for identification are occasionally got.

The Messrs. Searles V. Wood, senior and junior, who twice examined my collection, confirmed my opinion as to the Crag character of several of the species; and Dr. Gwyn Jeffreys, who looked at them in passing here a good many years ago, came to the same conclusion. The shells have a decidedly older and more fossilized appearance than those from our Scotch glacial beds; and some of them are filled with a hard calcareous paste or concrete, which is another feature that serves to distinguish them.

My residence in the neighbourhood has given me many opportunities of studying the subject more perfectly since my former communications to the Society; and as frequent reference has been made to these gravel-beds by Mr. Searles V. Wood, and others, and as a good deal of doubt has arisen as to their true age and position, I shall in the following pages point out their exact place in the series of superficial beds and give a list of all the shells that have been identified from them.

Although no doubt could be entertained that the shells themselves were older than those previously reported from any of our Scotch glacial beds, it was by no means so clear what was the age of the gravel containing them. Judging from its fossil contents and from certain other circumstances, I at one time thought that some part at least of the gravel itself might be a preglacial deposit of Crag age; but I afterwards ascertained that what appears to be a glacial bed underlies it, and I therefore now believe that in their present state these accumulations are really all of more recent origin than their fossil contents would indicate, and that the shells,

Fig. 1.—*Map showing the Localities of the Shelly Gravel of Aberdeenshire.*



along with much of the mineral débris, have been derived from the destruction of strata of older date that existed probably somewhere in the neighbourhood before the glacial period began.

The species of Mollusca seem to indicate that the Red Crag was represented (and perhaps even the Coralline), together with probably some of the later Bridlington or Chillesford beds; but here we have nothing but the débris, the mere wreck of these deposits.

As no Crag fossils have been found in any other part of Scotland (although they occur in Iceland), their existence here is a matter of some interest, and may help to throw light on the history of the last modifications which the surface of the country has undergone.

Extent and Distribution of the Gravel. (See Map, fig. 1.)

So far as I have been able to discover, the deposit of sand and gravel containing these shells is confined to the district of Slains and Cruden, which are two parishes situated on the east coast of Aberdeenshire, to the north of the river Ythan, between the seaport towns of Aberdeen and Peterhead, but nearest to the latter place. In no other part of Aberdeenshire or of Scotland have I met with it. I have, however, got a large and nearly perfect valve of a characteristic Crag shell (*Astarte mutabilis*), which was sent me from a railway-cutting a few miles to the west of Peterhead, where it occurred in a bed of red clay of glacial age. This shell contains some of the same peculiar concrete already mentioned, but is in a better state of preservation than any of my specimens from Slains and Cruden.

The part of Slains and Cruden to which the shelly gravel seems to be confined is bounded on the east by the sea, on the south by a desolate tract of blown sand called Forvie, on the west by a small stream known as the Burn of Forvie, and on the north by another small stream called the Water of Cruden. The gravel, however, does not cover the whole or even the greater part of this district, which embraces an area of about twelve square miles, forming a tract of bare undulating ground, all under cultivation and culminating in an eminence named Highlaw, the top of which is 300 feet above the present level of the sea. This Highlaw is situated not exactly in the centre of the district, but somewhat to the north of the centre; and from it the ground slopes away on all sides in gentle undulations, most of it lying at altitudes of from 100 to 200 feet. The coast-line is for the most part formed of steep grassy banks and rocky cliffs, generally about 100 feet high.

The distribution of the gravel within this district seems confined for the most part to an irregular belt of ground sweeping round Highlaw as a sort of centre, and at a distance of a mile or two from it. It extends furthest from Highlaw in a south or south-west direction, near to the fishing-village of Collieston, which lies on the coast about $3\frac{1}{2}$ miles off; and along its whole extent this shelly gravel seems to have been arranged in a series of mounds or

undulating ridges, like eskers or kaims, although their outlines are now obscured and softened in many places by a subsequent deposit of red clay which lies above the gravel.

Commencing at Collieston, we can trace the gravel running inland in a north-west line by the Cothill Loch, the Loch of Slains, and then northward through the lands of Leask as far as the farm of Belscamphie, a distance of about $3\frac{1}{2}$ miles. Its average breadth along this tract may be stated at from half a mile to a mile. From Collieston the sand and gravel also extend northward along the sea-cliffs for nearly a couple of miles, ranging over the farms of Kirkton, Moss of Slains, and Clochtow. In this direction it is generally covered by the red clay; so that its boundary cannot everywhere be made out. It occurs, however, in a pit near the farm-steading of Brownhill (about $2\frac{1}{2}$ miles north from Collieston), which appears to be near its extremity in that line. To the north of the Burn of Clochtow I have found none of it along the sea-cliffs; and it seems to be absent over the district between that streamlet and Cruden Bay, except on the farms of Brownhill and Ward.

Along the south side of the Water of Cruden, it occurs on the lands of Ardiffery, near the village of Hatton; and I have traced it in that neighbourhood on the farms of Auchinten, Standing Stones, and Ardiffery.

On the north of the Water of Cruden it seems to be absent, except it be on the farm of Auchlethen, close beside Hatton, where there appears to be a small patch of it.

The shelly gravel reaches its greatest height above the sea in the neighbourhood of Leask and Auchinten, where I have found it up to an altitude of 225 feet; and a large proportion of it lies at an elevation of from 100 to 200 feet.

At the Loch of Slains it forms a narrow prominent ridge, called the Kippet Hills. This ridge may be traced for nearly a couple of miles, running from Cothill to Knaps Leask, but is highest and best defined beside the Loch of Slains. The Ordnance Survey shows that the highest point of the Kippet ridge is 216 feet above the sea and 80 feet above the surface of the loch beside it; and the whole of the ridge at this point seems to be composed of the gravel from top to bottom. This is also one of the best localities for the shells.

Internal Structure and Contents of the Gravel Ridges.

The character of the gravel and its arrangement in these ridges are similar to what we see in a kaim, esker, or moraine—loose incoherent gravel heaped together in confused masses, or in irregular undulating beds, no two sections quite the same. Some portions consist of fine sand, some of fine gravel; but by far the greater part is a coarse pebbly gravel, with occasional clusters of large stones from 6 inches to 2 feet (rarely $2\frac{1}{2}$ feet) in length. The stones and pebbles are for the most part subangular or partially rounded, some of the larger ones quite angular; and there is a general absence of

smooth finely-rounded pebbles, such as we see on a sea-beach, although a few small ones of this sort may be found. The whole of the materials—the fine sand, gravel, pebbles, and larger stones—may occur in any relation to each other, there being no regular order or succession. Generally the materials are well washed, as if they had been tossed about in water; but occasionally the gravel is of a muddier character, and sometimes passes into an unstratified heap of coarse stony rubbish. As a rule, however, the materials are so incoherent that, when excavations are made, the stuff is continually tumbling down, and no clear section remains long exposed. It is exceedingly rare to find any trace of glacial scratching on the stones—so much so, that I at one time thought it never occurred; but I have recently found at least one instance of it, although in this case the scratches were nearly effaced. The absence of the glacial striæ is the more remarkable, seeing that the mineral quality of many of the stones is well adapted for receiving and exhibiting them.

Small pieces of broken shells, very much worn, are pretty uniformly but very scantily dispersed through these ridges, from the very surface down to the bottom as far as the excavations have gone; and they are often as frequent on the surface, I think, as in the interior. This is a circumstance of some interest, as the unfossiliferous character of many eskers and gravel-beds has been attributed to the agency of rainwater &c. dissolving the shells they had once contained. The shelly material occurs generally in the form of fine pounded débris and small worn crumbs, with here and there a larger bit, generally a hinge of *Cyprina*, *Astarte*, or *Venus*.

The bottom of the gravel has not been reached anywhere in the Kippet Hills, so far as I know; I am therefore unable to say what it rests upon there; but it is covered in some places by a mass of red clay, in which some ice-scratched stones are occasionally to be found. This clay seems to have suffered denudation, and is absent along the crest of most of the ridge, although a patch of it may here and there be found; on the gentler undulations it is more frequent. The steep slope of 25° to 35° which occurs along a part of the Kippet ridge, near the Loch of Slains, appears to be due to some action that has taken place subsequent to the deposition of the red clay; but it is also evident that the clay reposes on an irregular, undulating, or ridgy surface of gravel, and that much of the gravel must have had a moundy outline when the clay first lodged on it.

In addition to the shells these gravel-beds are distinguished by containing many pieces of grey and yellow limestone and calcareous shale, which look as if they were derived from rocks of the Permian or Oolitic formations. And I find all over Slains and Cruden, wherever these shells occur, that this limestone débris invariably occurs along with them; so that it has apparently formed part of the material which composed the original strata that furnished the shells. I have seen no limestone-rocks of this nature in Aberdeenshire, and am unable to point out the source whence the fragments have been derived. In addition to the limestone débris, bits of red and

grey sandstone also occur. Taking 100 stones at random from a pit in the Kippet ridge, I found them to consist of

Gneiss and mica-schist	68
Grey and yellow limestone	20
Granite	7
Sandstone	3
Felspar porphyry	2
	100

In addition to these, fragments of greenstone occur, and a flint may now and then be found. I have likewise observed a few pieces of serpentine.

The Coast Section. (See fig. 2.)

The base of the shelly gravel is at present nowhere displayed, except along the coast-line, and may be best studied between Collieston and the old castle of Slains, a distance of little more than a mile. Between these points the nature of the section is as follows:—At the bottom we have the gneiss or mica-schist (fig. 2, *a*), usually forming a cliff from 30 to 60 feet high. The surface of the rock, so far as I have seen, is not smooth and glaciated, but is commonly of a worn subangular character, occasionally somewhat fissured and disintegrated; and detached pieces of the rock are often plentifully mixed with the overlying bed. Resting immediately on the surface of the rock there is generally a stratum of grey rubbish (*b*), usually from 5 to 10 feet thick, which sometimes has the appearance of a mass of disintegrated gneiss, like that beneath, but more commonly consists of small pieces of gneiss and mica-schist, with some pebbles of granite and now and then a boulder of greenstone, packed in a matrix of fine débris of the same mineral nature. This grey stuff is more loose in texture than the Boulder-clay usually is, and not so hard, tough, and impenetrable. The reason appears to be that it contains less clay or fine muddy sediment; and perhaps also it has undergone less compression. In one or two places to the north of Collieston, it contains broken pieces of the Crag shells and bits of the limestone mixed through it; but this is so exceptional that it may be owing to accident. No glacial markings have been observed by me on any of the stones in this grey stuff at the base of the section between Collieston and the old castle; but ice-scratched stones do occur, although not very commonly, in what appears to be the same bed, to the north and south of these points, while the character of the stuff assimilates more to the nature of an ordinary Boulder-clay. I therefore think that this stratum of grey rubbish, which is very uniformly present along the coast of Slains and Cruden, covering the surface of the rock to a depth of from 5 to 10 feet, must be a deposit of the glacial period, and has probably been the result of a sheet of land-ice acting on the surface of the country.

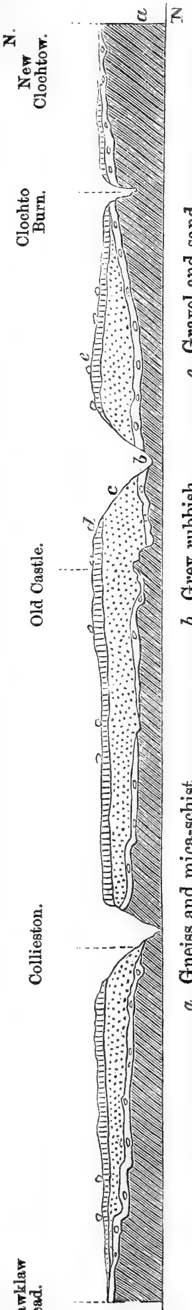


Fig. 2.—*Coast-section from Hawklaw Head to New Clochtow.*
(Length of Section, about 4 miles. Height, from 90 to 120 feet.)

a. Gneiss and mica-schist. *b.* Grey rubbish. *c.* Gravel and sand.
d. Red clay. *e.* Boulders.

In some of the cliffs about half a mile to the north of Collieston this grey stuff seems to thin out; and the lowermost bed next the rock consists of a mass of loose pebbly gravel and sand, exactly the same as that of the Kippet Hills, with abundance of limestone débris and frequent crumbs of shells. This coarse pebbly gravel is seldom more than 5 feet deep (but in one section there are 16 feet of it); and it passes up into a thick mass of fine brownish sand, with occasional streaks of gravel. This sand and gravel (*c*) form a large part of the sea-banks along the coast of Slains; and in some few places they lie, as I have said, upon the surface of the gneiss rock, without the intervention of any noticeable bed of other stuff between them; but as a rule they repose upon the top of some thickness of the grey rubbish I have just described. The thickness of the sand and gravel is often very great, from 40 to 60 feet being not uncommon between Collieston and Clochtow. Occasionally the whole mass is composed of fine, soft, brownish sand, without stones of any kind; and in these cases no shells are met with, or only some very fine shelly dust. Generally there are some streaks and seams of reddish sandy clay or silt interstratified with the brownish sand, especially towards the top; and the sand in these places is often tinged with red. In other places the sand is varied with seams and irregular undulating beds of pebbly gravel or coarse sand; and in these we generally find some of the limestone débris and crumbs of shells.

I have not observed any large boulders imbedded in this deep mass of sand and gravel, which extends along the coast all the way from

Hawklaw Head northward to near the Burn of Clochtow, a distance of about 3½ miles. The shells and limestone débris, however, are mostly confined to that portion which lies between Collieston and the old ruined Castle of Slains. Beyond these points some calcareous powder or shelly dust may be found in the sand; but I have got nothing larger. Hawklaw Head is a rocky promontory about a mile and a half to the south of Collieston.

Lying on the top of the sand and gravel, there is generally a bed of red clay (*d*), varying in thickness from 1 to 15 feet or more, which usually forms the top of the banks facing the sea. Some large transported boulders of granite, greenstone (*e*), and gneiss occasionally occur in this clay or on the surface of it. It extends over a large part of Slains, and seems at one time to have covered the whole parish; for it reaches up the sides of Highlaw nearly to the very top, and likewise spreads over much of Cruden. This clay, to which I have devoted another paper, represents the period of submergence during which the beds of brick-clay containing marine fossils of arctic type were deposited over the low grounds along the east coast of Scotland—the "*glacial marine*" beds, as I have elsewhere termed them.

Order of Succession and Derivation of the Beds.

Such, then, is the succession of deposits along the coast of Slains, between Hawklaw Head and Clochtow. At the bottom is the gneiss, covered by a stratum of coarse stony rubbish, supposed to be of glacial origin; then comes the thick mass of gravel and sand; and above all, the red clay. The bed of coarse stuff at the bottom seems to represent the old Boulder-clay of this part of Scotland, formed beneath the ice-sheet which covered the country before the period of submergence. The red clay represents the period of submergence; and the gravel and sand lying between the two must therefore be of intermediate age.

The gravel-ridges of the Kippet Hills and other mounds in the neighbourhood seem to me to be deposits of a morainic character, which have been formed along the margin of a glacier or where two glaciers met. The ice had probably moved over the locality where the Crag-beds existed; and the gravel, I imagine, represents the scourings of the surface which the ice carried along with it and shed off along its border. The washed character of the gravel indicates the presence and action of water, which has tumbled about the stones, effaced the glacial striæ, and carried off the muddy sediment. The shells and limestone débris may therefore have been brought from some distance, and perhaps from a lower level. All this must have happened before the time represented by the red clay, which lies above the gravel.

The thick masses of fine sand that occur along the coast-section and in some other places, may have been washed out of the gravel-mounds into the hollows and lower depressions of the coast at the commencement of the period of submergence represented by the red

clay; for in those sections where the two occur together the sand lies above the pebbly gravel and seems to graduate upward into the clay. It likewise usually contains seams of red clay and silt interlaminated with it, especially in the upper half; and very possibly part of the sand may have been a precipitate from the muddy water in which the red clay was suspended. These thick masses of sand seem to be confined to the lower levels, and do not range up to the same height as the pebbly gravel and red clay. I have never found any shells in the sand that appear to be contemporaneous with the time of its deposition.

The gravel of the Kippet Hills occasionally contains rolled calcareous nodules, in which fragments of shells may be perceived. These calcareous nodules seem to be of the same nature as the concrete or hard paste that fills some of the shells; and the shells containing this concrete have been broken, rolled, and worn after they were filled with it. Mr. Searles V. Wood considers that this fact proves the shells to be derived from beds of older date than the gravel now containing them—an opinion in which I concur. This shows that remains of marine shells may be found in glacial deposits and yet afford no proof that such deposits were accumulated by the sea.

If a distinctive name is wanted for this shelly gravel, it might be termed "*the Slains Gravel*," as it is best developed beside the Loch of Slains; while the deep mass of sand might be called "*the Collieston Sand*," as it is well displayed beside that village.

The bed of coarse grey stuff at the bottom of the sections differs decidedly from the shelly gravel above it, and indicates transport from a different direction and under different conditions. Its colour, texture, and mineral contents are all different. Glacier ice covering the country might accumulate such a mass beneath it. In the district of Slains the surface of the rock is seldom exposed, except along the coast, and no glacial markings have come under my notice; but further inland, in the Ellon neighbourhood, the direction of the ice-scratches below the old Boulder-clay is generally nearly E. and W., as if caused by ice coming from the westward and moving towards the coast; while the ice-worn rocks are covered by a bed of grey Boulder-clay, which differs from that of the coast-section chiefly in being harder, tougher, and more full of ice-worn stones of various kinds; and above it we have in many places a bed of red clay identical in appearance with that found in Slains. It seems to me, therefore, that the bottom bed of the coast-section has been the result of land-ice also; but the fact of its mineral contents often consisting almost wholly of the débris of the adjacent rock implies a more local origin.

The shelly gravel, however, seems to have come from some other direction; and if so, it indicates a change of movement in the transporting agent. The fact of its containing pieces of serpentine, like that which occurs *in situ* at Belhelvie, ten miles to the south-west,

may afford us some clue to the line in which the transporting agent moved. The overlying mass of red clay, as I have shown in another paper, also indicates a drift from the southward. We may therefore suppose that in the Slains district, after the deposition of the grey Boulder-clay, there had been a change in the movement of the ice, bringing it more from the southward, which may have had something to do with the accumulation of the shelly gravel. I incline to think that some patch of Crag may have occurred along the coast, or occupied part of the low ground near the estuary of the Ythan, and had been scoured out by the ice coming across it from the southward. The absence of shells and limestone débris in the bottom bed of grey rubbish along the coast of Cruden and Slains seems to show that the ice which lodged this grey rubbish did not move over the supposed Crag beds; otherwise their débris would have been mixed up with the grey stuff. Nor have I ever seen a trace of this débris in the Ellon district, to the westward of Slains; but I have got some small pieces of apparently the same sort of limestone to the south-west, in the parishes of Logie Buchan and Foveran, imbedded in the subsoil, which affords a further indication as to the direction from which the transporting agent came.

On the north bank of the Ythan, near the iron bridge at Newburgh, there is a thick mass of gravel and sand, covered by a bed of pebbly red clay. This gravel much resembles that of the Kippet Hills; but I could find no shells or limestone débris in it.

Along the coast to the south of the Ythan, in the parish of Foveran, at a place called Drums, there are some long gravel-ridges, or kaims, which appear to be older than the Red Clay, seeing that patches of it lie on the top of them. These gravel-ridges contain many pieces of red sandstone and serpentine; but I could see no shells or limestone in them. They run in a direction from N. to S. and S.W., and may be traced for three or four miles from Newburgh, on the river Ythan, southward to Menie, in the parish of Belhelvie. Possibly they may indicate the margin of that ice-stream which came along the coast from the south, to which reference is made in my paper on the Red Clay.

List of the Shells.

	Coralline Crag.	Red Crag.	Norwich Crag.	Bridlington Crag.	Middle Glacial of S. V. Wood.	Scotch Glacial.	Living.	Living on the British coast.
1. Astarte mutabilis	*	*	...	*				
2. Artemis lincta	*	*	?	...	...	?	*	*
3. Cardium edule	*	*	*	*	*	*	*	*
4. Cyprina islandica	*	*	*	*	*	*	*	*
5. —— rustica	*	*						
6. Fusus antiquus (dextral form)...	...	*	*	*	*	*	*	*
7. —— ——, var. carinatus (do.) ..	...	*	*	*	...	...	*	
8. —— ——, var. contrarius	...	*	*	*				
9. Nassa reticosa.......................	...	*	*					
10. Nucula Cobboldiæ..................	...	*	*	*	*	...	? Japan	
11. Panopæa Faujasii ?	*	*						
12. Pecten maximus ?	*	*	...	...	...	?	*	*
13. —— opercularis	*	*	*	...	*	?	*	*
14. Pectunculus glycymeris (large form)	*	*	...	...	...	...	*	*
15. Pholas crispata	*	*	*	*	*	*	*	*
16. Purpura lapillus, var. incrassata	...	*	*	...	*			
17. Tellina balthica	...	...	...	*	*	*	*	*
18. Trophon costiferum ?	*	*	?					
19. Turritella incrassata	*	*	? *	...	*	...	*	
20. Venus casina	*	*	...	...	...	?	*	*
21. Voluta Lamberti	*	*	...	...	...	...	? Mexico	
22. Mactra sp.								
23. Mya sp.								
24. Glycymeris sp.								
25. Pileopsis sp.								
	14	20	11	9	9	5	12	10
=per cent.	67	95	52	43	43	24	57	48

It will be seen that the group is most nearly related to the Red Crag, all the species being found there save one, viz. *Tellina balthica*. Messrs. Searles V. Wood maintain that this shell does not occur in the Coralline, Red, Norwich, or Chillesford Crag beds of England, although it is found at Bridlington and in all the later glacial deposits. But there would be nothing surprising in its inhabiting the Aberdeenshire coast at the Crag-period, although absent from the shores of Norfolk.

It is, however, by no means unlikely that the deposits from which the Slains shells were derived may have included different members of the Crag series, and even some of a later stage. But the presence of *Voluta Lamberti*, *Astarte mutabilis*, *Trophon costiferum*, *Nassa reticosa*, *Fusus contrarius*, and *Cyprina rustica*, together with the prevalence of the large form of *Pectunculus glycymeris* and of *Venus casina*, affords good evidence that some bed as old at least as the Red Crag of Norfolk must have contributed to the remains.

Mr. S. V. Wood, informs me that the large *Pectunculus* "distinctly dies out as we ascend the Crag series, swarming in the Coralline Crag and in the older part of the Red. In the Norwich, or fluvio-marine, Crag only one small specimen has ever been said to have occurred; and in the Chillesford shell-bed, which is the sand immediately underlying the Chillesford clay, only one small much-worn valve has ever occurred, though these deposits have been most assiduously hunted by various collectors. In the lower glacial we have never seen a trace of it. On the other hand it is very common in the middle glacial, but *always small*, the larger specimens fragmentary, but the fry quite unworn and perfect." Mr. S. V. Wood, also conments on the absence of *Tellina obliqua* from among the Slains specimens. This shell, he says, "swarms in all the newer beds of the Crag and in the Lower Glacial, and occurs, although not common, in the Middle Glacial; but it is unique at Bridlington. *T. prætenuis* is also a swarming Crag shell, but not common in the Lower Glacial, and not yet met with in the Middle Glacial or at Bridlington. The newer beds of the Red Crag, the Norwich Crag, and the Chillesford beds are almost made up of these two Tellens; and it is very odd that in such a case no trace of them should occur with you." (*Letter of date* 25 *March*, 1870.)

Pecten maximus, *P. opercularis*, *Venus casina*, and *Venus* (*Artemis*) *lincta* appear in some lists as Scotch Glacial species; but there is great doubt as to the correctness of this. The careful researches of Messrs. Robertson and Crosskey would seem to show that they do not occur in the true glacial beds of Scotland.

Hinge-fragments of *Astarte* are common in the Slains gravel, and appear to represent more than one species; but they are too worn and imperfect for satisfactory determination. I have several pieces of *Fusus contrarius*, which seems to have been more common than the dextral variety, and also a few of *Nassa reticosa*; of *Nucula Cobboldiæ* only one hinge-fragment, but showing traces of the zigzag markings characteristic of this species. I found it near the very bottom of the deep mass of sand in the coast-section at Collieston. Of *Purpura incrassata* I have three specimens, quite characteristic, and two of them nearly complete. Of *Trophon costiferum* I have only one small young specimen, nearly complete, but much worn. Both the Messrs. Wood and the late Dr. S. P. Woodward, who also saw it, think it probably this species.

Of *Turritélla incrassata* I have only a few fragments; but the Messrs. Wood pronounced them to be undoubtedly this shell. Of *Voluta Lamberti* I have only one clear specimen, which consists of the very characteristic columella or pillar of a large-sized individual, much worn, but quite unmistakable; I found it in the gravel of the Kippet Hills, near the Loch of Slains. Fragments of *Pectunculus glycymeris* are not very rare; and most of them indicate a large size of shell, such as occurs in the Red and Coralline Crag.

Small pieces of *Pecten* are very common; but they are too fragmentary and worn for satisfactory identification. Most of them seem to agree with *P. opercularis*, so far as they go.

Pieces of *Cyprina islandica* are numerous, the strong massy hinge of this shell having withstood the tear and wear better than most others; a few of them are filled with concrete.

I have a good many hinge-pieces of what I believe to be *Cyprina rustica*; but I must candidly mention that the Messrs. S. V. Wood expressed themselves doubtful as to their identification, thinking they might belong either to this species or to *C. islandica.* I feel confident, however, that they are not the latter, as it is a shell I am quite familiar with in all states of preservation, it being perhaps the most plentiful of all our glacial Mollusca, and also quite common on the Aberdeenshire coast at the present day; and I find no difficulty in distinguishing its hinge from these specimens of *C. rustica.*

In regard to the shell-fragments as a whole, the question naturally arises whether some of them may not be of glacial age, contemporaneous with the period during which the gravel was accumulated. So far as I can judge from their appearance and state of preservation, I incline to think this question must be answered in the negative, and that the shells are probably all derivatives from older strata, and none of them of the glacial age to which the accumulation of the gravel itself must be assigned.

Details of a few Sections on the Coast of Slains.

1. *Section on the Coast immediately to the South of the Old Castle of Slains.*

Commencing at the bottom at high-water mark we have:—

		feet.
1. Mica-schist	about	50
2. Stratum of coarse grey rubbish		10
3. Pebbly gravel		16
4. Fine gravel, sand, and silt		22
5. Reddish clay		11
	Total	109

The coarse grey rubbish next the rock is here made up almost entirely of the débris of spotted mica-schist, apparently the same as that of the subjacent rock (andalusite schist). It appears to contain none of the limestone débris or broken shells. The schistose fragments in it are angular, and show no marks of glaciation, so far as I observed. The mass appears to be quite unstratified; and the included fragments lie in all positions and are packed in small débris of the same nature. The proportion of fine impalpable mud is small compared with what is seen in a typical Boulder-clay, such as that at the Bay of Nigg.

Lying immediately above this grey rubbish there is a bed of coarse gravel and sand containing shell-crumbs and small limestone débris. It is an open washed gravel, quite unlike the stuff beneath, and meets the latter suddenly without graduation or intermingling. This coarse sand passes quickly up into an unstratified mass of loose

rough pebbly gravel, composed of gravel, sand, and stones, all water-washed and partly water-worn. The stones are of all sizes up to a foot or a foot and a half in length. They consist of many kinds of rocks. Gneiss and spotted mica-schist predominate; but there are a great many pieces of yellow limestone, grey limestone and shaly limestone. Several fragments of purplish red sandstone, some of granite, one or two of serpentine, and a flint may be also found. In form the stones are for the most part subangular; but some well-rounded pebbles also occur. Small crumbs of shells are disseminated all through this pebbly gravel; and in it I got a small specimen of the Crag shell *Fusus contrarius*, var. *carinata*, much worn. This mass of rough pebbly gravel does not seem to extend continuously along the bank with the same thickness for any great distance. In general appearance and composition it seems identical with the gravel of the Kippet Hills.

Above it there is a thickness of 22 feet made up of fine brownish grey sand with seams of coarse gravel and reddish silty sand alternating with one another. Crumbs of shells and small limestone débris occur in the seams of coarse gravel all the way to the top, where it meets the over-lying clay, the junction with which forms an irregularly undulating line, as if the sandy beds had suffered some denudation.

The bed of clay forming the top of the bank at this spot seems to be a mixture of red clay with some patches of a coarse grey clay intermingled; but it is not very fully exposed. There are several stones in it, of all sizes, up to $2\frac{1}{2}$ feet in length, and of various kinds, viz. gneiss, mica-schist, granite, and greenstone. This clay shows no distinct stratification, and is of coarse quality and not laminated.

2. *Section at Clochtow.*

	feet.
Schistose rock	30
Grey rubbish	11
Fine sand and silt	56
Coarse clay	24
Total	121

In this section the coarse grey rubbish next the rock resembles that in the section already described, consisting of small rock-débris packed in a little muddy matter of the same mineral nature. Here the rough pebbly gravel is wanting, and the thick mass of sand and sandy silt seems to contain scarcely any stones or pebbles of any kind.

There is even an absence of small gravel, the whole mass being fine-grained, and consisting of brownish-grey sand interstratified with beds of reddish clayey silt and reddish sand, which appear to occur in all parts of the mass; but the red tinge seems to prevail more towards the top. The meeting of this thick mass of sand and silt with the coarse grey rubbish beneath appears to be sharp and sudden; there is no graduating into each other, so far as I could see. At the top, where it meets the overlying clay, the line of junction seems to be undulating. This clay above it is not very extensively

exposed; most of it appears to be red; but there seem to be patches of coarse grey mud containing small stones intermingled with it. Although no large boulders are to be seen in it, yet some occur on the top of the bank about 50 yards off, one of them 5 feet in length. They are of granite, gneiss, and greenstone.

3. *Section at Perthudden Bay, near Collieston.*

	feet.
Gneiss	24
Coarse grey rubbish	8
Sand and silt	55
Red clay	16
Total	103

In the bed of coarse grey rubbish next the rock in this section I found one or two small stones distinctly ice-worn and scratched. There is no bed of rough pebbly gravel here; but in the thick mass of fine sand and silt there are, near the bottom, some seams of coarse sand or fine gravel in which crumbs of shells and limestone occur. The fine sand lies in undulating masses, and is of a brownish-grey colour, with seams of reddish sandy clay interlaminated with it. The bed of clay at the top is of a reddish colour, with scarcely any appearance of stratification. Much of it is fine-grained; and some of it is laminated. No large boulders are seen; but a small stone may be got here and there in it. In one spot, pretty deep down near the bottom of the clay, I found a patch of dark brownish red coarse clay containing small stones and bits of broken shells (*Cyprina islandica* and *Astarte borealis*). This portion shows no distinct lamination or stratification, but contains irregular films and nests of sand, and is hard, tough, and compact in texture. The stones in it are chiefly of granite and quartz; but there are also some bits of yellow limestone such as occur in the gravel.

This variety of clay does not seem to extend continuously along the bank, but appears to be confined to a small spot, as if some frozen mass of pebbly shelly stuff had been dropped here amongst the fine red mud.

Discussion.

Mr. De Rance was unable to understand how Red-Crag shells could have been preserved in glacial drift. He disagreed with those who do not admit the possibility of southern species living on in the seas of the Glacial period.

Mr. R. Bell remarked that *Tellina balthica* had never been found in any southern Crag locality; and it was very remarkable to find it in any deposit containing undoubted Crag shells.

Prof. Judd stated that the author had pointed out that *Tellina balthica* may be of the age of the accumulation of the gravels, while the other shells are derived; or the shell may have lived in northern regions in Crag times, though it did not flourish in more southerly seas.

16. *On the* Red Clay *of the* Aberdeenshire Coast *and the* Direction *of the* Ice-movement *in that quarter*. By Thomas F. Jamieson, Esq., F.G.S. (Read March 8, 1882.)

Contents.

1. General Distribution and Character of the Clay.
2. Its Mineral Contents.
3. Drift from the Southward.
4. Change of Direction in the Ice-flow.
5. Organic Contents of the Clay.
6. Progress of the Submergence.
7. Northern Limit of the Red Clay. Blue Clay of the Banffshire coast.
8. Direction of the Ice-flow to the South of Stonehaven.
9. Reappearance of the Glaciers, and Denudation of the Red Clay.
10. Upper Limit of the Submergence.
11. Geological Date of the Submergence.
12. Explanation of the Section at the Bay of Nigg.

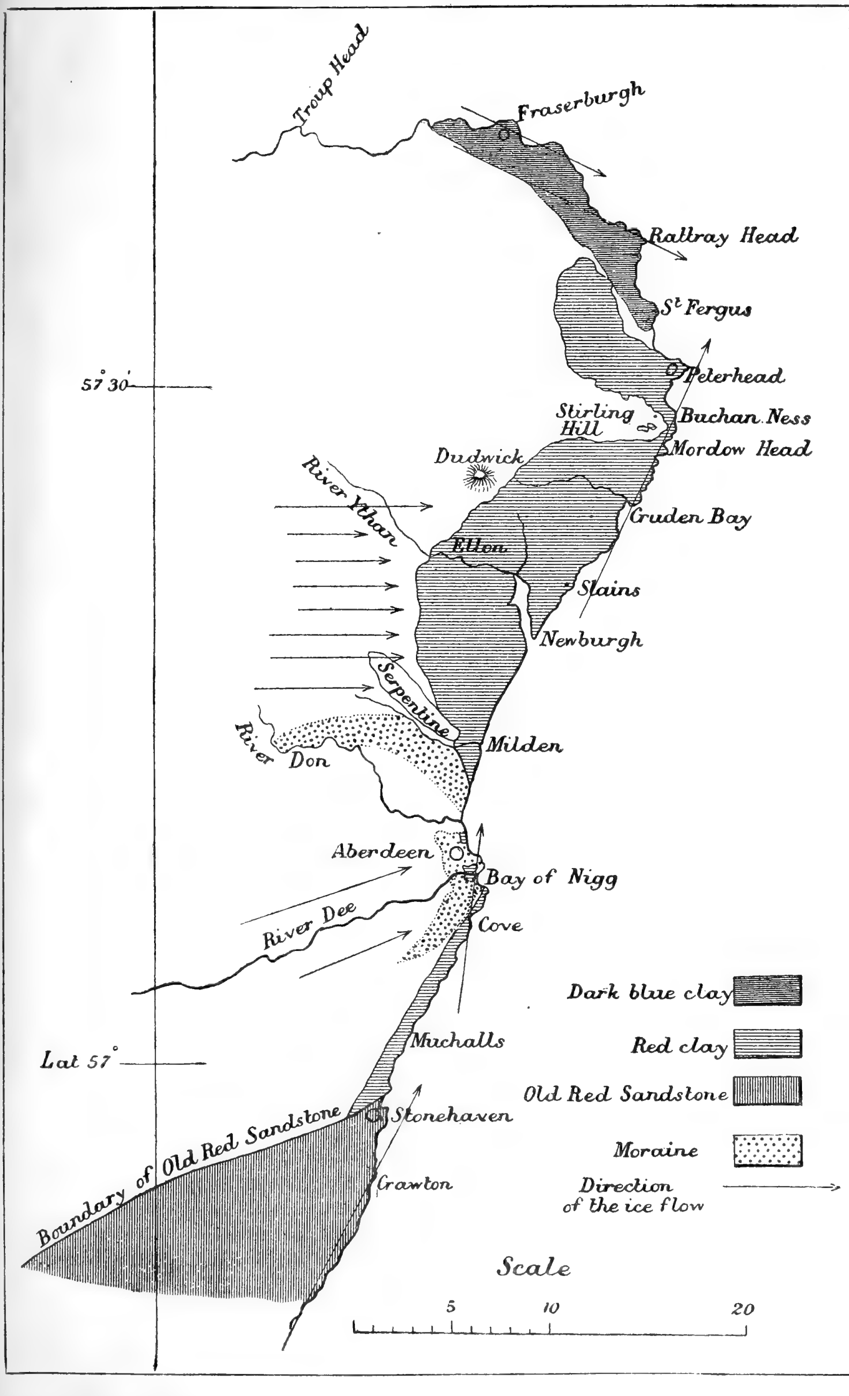
1. General Distribution and Character of the Clay.

The more we know of the Glacial period the more evident it becomes that it embraces a long and complicated series of changes which will require much patient study to understand; and some districts are found valuable as presenting clear evidence of certain events which cannot be discovered from the appearances we find in other quarters.

The Aberdeenshire coast is one of those districts. On the eastern side of that county we find a well-marked bed of red clay, which covers much of the low ground along the coast between Aberdeen and Peterhead, and extends some distance to the north of the latter town (see Map, fig. 1). It ranges from the sea-level up to an altitude of 300 feet, but is scarcely seen at heights beyond that, although there are here and there some indications of it at a higher level. It stretches inland along the course of the various streamlets which come down to the coast, and appears to have subsided most thickly in the depressions that intervene between the low eminences of gneiss and granite which constitute the rocky framework of the district. In some of these depressions patches of it are found of great thickness and purity. A depth of twenty or thirty feet may occur in which few stones or pebbles of any kind are to be seen. These masses, however, are usually of very limited extent; and commonly the clay is much thinner and coarser, with some pebbles and occasionally large boulders interspersed through it, while sometimes it is so coarse as to assume the character of a Boulder-clay. The finer kinds of it are often delicately laminated, and occasionally pass gradually into beds of a more sandy nature, or have seams of sand interstratified with them.

Now this clay is not such a deposit as would be derived from the rocks of the district in which it occurs; for the grinding down of the gneiss and granite gives rise to sediment of a grey colour, generally somewhat bluish-grey where the gneiss predominates, and of a more brownish tint where the granite prevails. This is well seen from the nature of the Boulder-clay covering these rocks, and which has

Fig. 1.—*Map of the Aberdeenshire Coast, showing the Distribution of the Red Clay.*



resulted from the triturating action of the glacier-ice passing over them. The red clay I speak of looks more like what we should expect to find in a district of Old Red Sandstone, being of a decided brick-red colour, exactly resembling the clay we find in the Red-Sandstone district of Kincardine and Forfar. How comes it, then, that a red clay of this nature should be found stretching so far over a tract of gneiss and granite which is covered by grey Boulder-clay of quite a different hue and character? For this red clay lies on the top of the grey Boulder-clay, and has therefore been laid down after it. The grey Boulder-clay itself seems to have been accumulated beneath a sheet of ice travelling from the interior of the country towards the sea; for beneath it we frequently find the surface of the rocks worn and scratched as if by the passage of a glacier coming from the westward, while the boulders and stones imbedded in it are such as would be furnished by the rocks that occur in the same direction.

2. Mineral Contents of the Red Clay.

Now the Red Clay is not only decidedly different in colour, but is further distinguished by containing stones that have evidently come from a different quarter. Very noticeable among these are certain large round pebbles of grey quartz with a smooth reddish exterior, such as are met with in the Old Red Conglomerate of Kincardineshire. They vary much in size: many of them are as big as a man's head, or even bigger; and they occur of all dimensions below that. They are often rubbed and scratched as if by the action of ice, and frequently worn to a flat sole on some of the sides, as if they had been ground down by long rubbing upon a hard surface. Their mineral character, reddish colour, and general appearance seem to show that they have come out of the Old Red Conglomerate; but there is another feature of a peculiar kind which serves still more certainly to identify them. In the Red Conglomerate rock of Kincardine and Forfar many of these pebbles have been split, fractured, and recemented while imbedded in the rock; and occasionally they are indented on the surface by the pressure of an adjoining stone, which has left a dint or depression in the exterior of the pebble, while here and there one may be seen quite distorted in shape, owing to the edges of the split pieces being shifted a little past each other as if by a fault or series of faults. These curious pebbles are very common in the Conglomerate near Stonehaven and in the Garvock hills, and were noticed long ago by Mr. Trevelyan. (Quart. Journ. Geol. Soc. vol. i. p. 147). Now many of the quartz pebbles we find in the Red Clay of Aberdeenshire exhibit all these features, which is a further proof that they have been derived from the Conglomerate. To make the matter still more sure, we find in some places fragments of the red sandstone itself, and also, more rarely, pieces of the conglomerate.

These reddish quartz pebbles occur all over the area covered by the Red Clay, and often in great quantity. They are very common in the parishes of Slains and Cruden, especially near the coast, and occur

also round Peterhead and even as far north as St. Fergus, which is 30 miles from Aberdeen and 45 from Stonehaven.

There is still more evidence to show whence the Red Clay has come; for in addition to the débris of the Old Red Sandstone itself we find many stones of a volcanic nature, unlike the rocks of Aberdeenshire or the North of Scotland, but resembling the masses of trap which occur in the sandstone district of Forfar and Kincardine. We also get bits of jasper, sometimes an agate, and pieces of a greenish stone like the hard-mud beds of the sandstone series, all which seems to point clearly to a drift from the southward; and when I add that this red clay may be traced continuously along from Stonehaven to Aberdeen, and thus into the Red-Clay district I am describing, the probability becomes very strong that the source of the clay is to be sought in the Red Sandstone and Conglomerate region to the southward.

3. Drift from the Southward.

That there has been a drift along the coast of some kind from the south is further shown by the transport of other rocks. About six miles to the north of Aberdeen, in the parish of Belhelvie, there is a ridge of well-marked rock composed of serpentine and diallage which has sent off a large number of heavy boulders. These are scattered along the coast to the north-east of the ridge in question, while smaller fragments are to be found more and more sparingly as we go northward towards Newburgh and Peterhead, a few occurring even beyond the latter town, while they seem absent to the south and west.

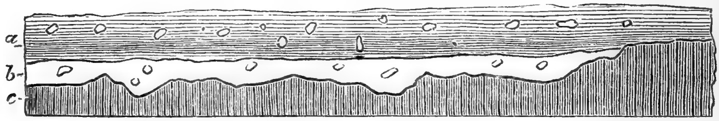
4. Change of Direction in the Ice-flow.

I shall now mention some facts I observed a good many years ago which have a bearing on the subject I am considering. Three miles along the coast to the south of Aberdeen there is a small fishing-village called the Cove, where there is a railway-station. Here there are some granite-quarries, where the surface of the rock exhibits clear marks of glaciation. The ice-grooves run in two directions, there being an older set and a newer. Both are well marked, the older set being perhaps the most extensively developed. In these quarries there are also two beds of Boulder-clay, an older and a newer, which afford a further means of distinguishing the relative age of the two sets of striæ. The lowermost and oldest clay is of a grey colour and contains fragments of gneiss and granite. It is chiefly seen in the depressions of the rock, where it has escaped denudation. The upper and newer bed is red in colour and contains many of the reddish quartz pebbles, derived apparently from the Old Red Conglomerate, and also pieces of volcanic rocks, neither of which seem to occur in the grey clay below. The difference in hue between the two clays is very distinct when newly excavated. Both are hard and tough and require to be broken up by the pickaxe, being impenetrable by the spade alone. Beneath the grey stuff the ice-grooves point about S. 70° W., varying, how-

ever, occasionally from S. 50° to 80° W., while the rubbed surface of the granite shows plainly that the ice has come from the westward and not from the east. Where the grey stuff is absent and the red clay lies next the rock the direction of the grooves is about S. 10° W. or 60° further south than the older set, and the action on the surface of the rock seems to show that the moving agent had come from the south and not from the north.

The accompanying section (fig. 2) will give some idea of the arrangement of the Boulder-clays.

Fig. 2.—*Section at Cove Quarry.*



a. Red Boulder-clay, 4–6 feet thick.
b. Grey Boulder-clay, 1–3 feet thick.
c. Granite.

This interesting locality proves that there has been a change in the direction of the ice-flow: the older stream has come from the interior of the country to the W.S.W., parallel to the strike of the valley of the Dee, bringing with it the grey débris of gneiss and granite; whereas the later stream has come nearly from the south, or parallel to the line of coast. This change has brought with it the red material from the sandstone district of Kincardineshire; and in following the coast north from Stonehaven I observed that the red Boulder-clay of that locality extended past the boundary of the Old Red Sandstone on to the gneiss rocks which range along the coast northward to Aberdeen; and I have traced this red Boulder-clay, full of Old Red Sandstone débris along the coast of Kincardineshire to within a mile of the town of Aberdeen.

More recently I have found evidence to show that this movement of the ice extended not only to Aberdeen, but continued along the coast on to the Buchan Ness, a rocky headland beside Peterhead, forming the most easterly point of the Scottish coast.

There are several granite-quarries in that neighbourhood; but the rock has generally little cover; and it is only where the surface of the granite has been protected by a covering of clay that the glaciation is likely to be preserved. The best instances I discovered were at a quarry on the top of a high rocky cliff called Mordow Head or Murdoch Head. Here there are from three to five feet of unstratified reddish pebbly clay covering the rock. This clay is quite full of the quartz pebbles from the Old Red Conglomerate and pieces of volcanic rocks. Where it has been recently removed, the surface of the granite beneath shows clear marks of glaciation. The striæ point S. 20° to 30° W., which is about parallel to the general trend of the coastline to the south of this point; and, so far as I could judge, the action had come from the S.W. and not from the N.E.

On the top of Stirling Hill, 260 feet high, close beside Buchan Ness, where the old quarries of red granite have long been worked, I also found evidence of glaciation, but not so well marked: the striæ are worse preserved; and the direction seems to vary more. So far as I could make out, they pointed at one spot S. 10°–20° W., at another S. 45° W., at another S. 25°–30° W.; and so far as I could form an opinion, the action had come from S.W. Some traces of the red clay occur here and there on the hill.

On the north brow of Stirling Hill I also found some instances of of the E. and W. glaciation. The surface so marked was of very small extent; but the striæ were distinct and pointed nearly due W. or W. 5° S. These are probably of older date, like those beneath the grey clay at the Cove; for at Peterhead Bay, just at the south side of the town, we find a thick mass of the same grey Boulder-clay, full of granite and gneiss débris, resting immediately upon the surface of the granite, which is here somewhat soft and disintegrated and does not bear signs of glaciation. Upon the top of this grey Boulder-clay at Peterhead Bay there is a heavy bed of the Red Clay, quite distinct in colour, and with fewer stones; it is not, however, so extensively or so deeply exposed as the grey clay beneath; but its position above the latter is at present very satisfactorily displayed.

The clear evidence at Murdoch Head shows that the ice from the southward came along the coast on to the neighbourhood of Peterhead, grazing the surface of the rocks at the projecting headlands and bringing with it the red clay and débris of the Sandstone formation; so that we have here the movement traced for a distance of 40 miles to the north of Stonehaven by its action on the rocks, while the Red Clay itself extends ten miles further. This flow of ice along the coast from south to north accounts for the drift of red sediment and sandstone débris which we find on the east coast of Aberdeenshire as far north as Peterhead, and likewise for the transport of the serpentine boulders in the same direction.

It is somewhat difficult to decide whether the ice which flowed northward along the Aberdeenshire coast was of the nature of a glacier or pack-ice, such as that which fringes the east coast of Greenland, where it drifts steadily along the margin of the land southwards to Cape Farewell, under the influence of the Arctic current. Such extensive sheets of ice, 30 or 40 feet thick, with bergs occasionally frozen into them and moving steadily along a coast, seem competent to exert some abrading action on the rocks; for in Nares's Expedition to the Arctic regions Capt. Feilden tells us that they obtained ocular demonstration that even the shore-ice, acted on by the rise and fall of the tide, picked up material from the bottom and scratched the imbedded stones as well as the rocks against which the ice grated*. It may be contended that the fine red mud might have been brought in suspension by the current of water which carried the floe on its surface, while the stones scattered through the clay may have been dropped from fragments of ice into

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 566, August 1878.

which they were frozen. The glaciation of the rocks near the Buchan Ness and Murdoch Head may perhaps not be thought sufficient to render it imperative to call in the agency of a glacier, although the red pebbly clay which covers them is unstratified; but at the Cove, I think, the appearances are more conclusive; for the red Boulder-clay there is very hard and tough, as if it had been pressed beneath a glacier. I therefore incline to believe that the glacier really did advance northward along the coast as far as Aberdeen, and may have even stretched past Peterhead.

In regard to the source of the red sediment, it must be kept in view that possibly beds of Red Sandstone and Conglomerate may occupy the present sea-bottom along the Aberdeenshire coast; for some little outlier patches are known to occur at Aberdeen, although too small to be shown on a map unless of a large scale.

Dr. R. Brown* has described how a deposit of fine clay, just like what we have in Scotland, is at present in course of formation on the coast of Greenland and in the fiords and bays of that country. It arises, he tells us, from the creamy mud produced by the grinding-down of the mineral matter beneath the glacier, and is carried along by the subglacial torrents issuing from the ice. The action of the waves beating upon the red Boulder-clay extruded from below the ice, or left behind it when it retired, would no doubt give rise to a similar fine mud, which would subside in the deeper depressions where there was still water.

The fact of the ice having changed its line of movement and come along the coast from the south is wonderfully in accordance with the views of Dr. Croll, who in his paper on the Caithness drift † boldly maintained that, owing to the shallowness of the sea between this country and Norway, the Scandinavian ice would not be able to float and break up into bergs like that of Greenland, but would be obliged to spread over the sea-bottom and advance towards Britain, so that the Scottish ice would be unable to move out to the eastward, and be compelled to turn along the coast in the direction it seems to have actually taken.

5. Organic Contents of the Clay.

The Red Clay is remarkably devoid of remains of animal and vegetable life. It is rare to find shells in it; and when they do occur it is always very scantily, and usually in broken fragments. I have never seen or heard of any sea-shells in the clay at Aberdeen itself, although some of the pits there have been wrought for many years. But they sometimes occur at a pit known by the name of the 'Black Dog,' five miles north of that town, and also here there in a few other places. The most common species are *Cyprina islandica*, *Astarte borealis*, and *Saxicava sulcata*, large form. The following are also occasionally met with, viz. *Astarte elliptica*, *Tellina balthica*, *Tellina calcarea*, *Pecten islandicus*, *Cardium echi-*

* Quart. Journ. Geol. Soc. 1871, vol. xxvii. p. 681.

† Geol. Mag. vol. vii. p. 1, May 1870; see also 'Climate and Time.'

natum, *Dentalium entalis*, *Turritella communis*, *Trophon clathratus*, *Littorina limata*, and *Panopœa norvegica*.

One or two instances have occurred of the remains of a small fish. Thus in 1870, at the Tipperty pit near Ellon, the skeleton of one was got about 12 or 15 feet below the surface; this I saw. The length of it was $4\frac{1}{2}$ inches, of which the head-like portion measured 2 inches. And at the pit at Torry farm, near Aberdeen, some vertebræ of a small fish were got in 1859, deep down in the bed of Red Clay. There have also been some instances of bird-skeletons.

Many years ago the skeleton of a bird was got in the Invernettie clay, near Peterhead, at the depth of about 30 feet beneath the surface. Mr. Yule, who had it in his possession for some time, told me it was almost complete and seemed to have belonged to a bird of large size.

In the Seaton clay-pit the skeleton of what seems undoubtedly to have been an Eider Duck was got. It is now in the Museum at Marischal College, and bears the following label, "Bones of Eider Duck, *Somateria mollissima* *, from Seaton brickwork, 17 feet deep. Donor, Alex. Nicol, Esq. Feb. 1875." It includes the upper part of the skull with the upper mandible, bones of the leg and foot and a large part of the rest of the skeleton. Another bird-skeleton was got in the same pit before, but not preserved.

In the Clayhills pit at Aberdeen the imperfect skeleton of what is thought to have been a duck was got a good many years ago, 30 feet beneath the surface in the Red Clay, and is also in Marischal College Museum.

Some imperfect remains of Starfishes (*Ophiura*) were also got at the same place, according to Prof. Nicol †.

In the Red Clay at Auchmaccy brickwork, part of a Seal's skull was got in March 1858, and was for some time in my possession.

Such is the meagre list of what has been found in this red clay of the Aberdeenshire coast. For a marine deposit the scantiness of fossils is surprising; for the greater part of it seems absolutely barren. So much is this the case that the late Dr. Fleming ‡, who knew it well, thought it must have been accumulated in the water of some immense lake into which the sea had made only a temporary irruption. The organic remains, however, such as they are, imply that the water was that of the sea; but their extreme scantiness seems to point to a sea in which marine life was far from abundant.

* Prof. Turner of Edinburgh, in his account of remains of Seals got in the clay-beds of Scotland (Proc. of Roy. Soc. of Edin. 1869–70, p. 105), mentions that Dr. Page informed him that nearly perfect skeletons of the Surf and Eider Ducks had been found in the Shatheden clay. Prof. Turner refers the Seal skeletons he examined to the Arctic sp. *Pagomys fœtidus*. The skull-fragment I got from the Auchmacoy clay may possibly have belonged to the same species. I sent it to Prof. Owen; but the great anatomist was probably too busy at the time, and I heard nothing of it.

† Brit. Assoc. Report for 1859.

‡ Lithology of Edinburgh, p. 80.

6. Progress of the Submergence.

It is worthy of notice that there is no evidence at the bottom of the clay of littoral Mollusca such as would indicate shore-conditions at the commencement of the submergence. The fine red mud implies deep, or at least quiet water; and as a rule it lies immediately upon the top of the grey Boulder-clay, without the intervention of any beach-gravel or sand between them, as if still water of some depth had at once taken the place of the glacier. This may be explained by supposing that at the beginning of the depression the glacier still occupied the surface and did not break up until a considerable amount of submergence had occurred. In this way deep water would take the place of the ice as soon as it floated off the bottom; and the red mud would then settle down upon the exposed surface of the grey Boulder-clay.

During the time the glaciers attained their full development there might have been a considerable depression of the land going on; but if the whole surface of Scotland was covered with thick ice, the sea would not gain admission to the depressed tracts until the ice was removed. In the Antarctic continent and some parts of Greenland a similar state of matters prevails. The glacier occupies the sea-bottom, excluding the salt water, and embraces many of the islands, insomuch that it is difficult to know whether the land is continental or consists of a group of islands soldered together by ice.

The evidence in Scotland seems to point to a somewhat similar condition. The whole country seems at one time to have been thickly clad with ice; and I believe the depression or submergence began when such was the state of affairs. But the beds of fine marine clay must have been deposited at a later stage, after the ice began to give way. The thinnest ice would yield soonest; and we might therefore expect it would be there the sea-water would make its first appearance.

The glacier-ice seems to have been less heavily developed on that north-eastern angle of Scotland which lies between the Moray Firth and the Firth of Forth than elsewhere; and we may therefore suppose that it would melt away most quickly in that quarter. The sea-water would therefore probably establish itself first in the neighbourhood of Peterhead and Fraserburgh, and thence creep south and west along the coast as the ice gradually broke up. But when the ice disappeared, it would seem that either the land began to rise again or the sea-level began to sink, so that the submergence became less and less and gradually came to an end. The submergence seems to have followed close upon the presence of the ice, and not to have endured long after the ice vanished. This appears to have been the case not only in Scotland, but also in other countries; so that it is difficult to avoid the conclusion that there must have been some intimate connexion between the two events.

As the submergence proceeded the glacier seems to have gradually retired, sending out red mud all along its margin. This recession went on until the ice left the Aberdeenshire coast altogether and

withdrew to the region whence it set out; for we find the Red Clay covering some of the low coast-districts of Kincardine, Forfar, Perth, and Fife, there being beds of it at Montrose and Errol containing marine shells and starfishes *in situ*, which proves that the ice had retired and the sea had taken its place. This submergence may be traced across Scotland south-westward to the neighbourhood of Loch Lomond, near which we find, at Balfron and elsewhere, beds of the very same sort of red clay, derived from the sandstone of that quarter, not far from the base of Benlomond, which shows that the glaciers had vanished from the low ground of Scotland at this time.

If I am right in my explanation of the origin of the Red Clay and the way in which the glacier retired, we may infer that the clay-beds at Errol and Montrose were deposited at a somewhat later date than the earliest of those on the Aberdeenshire coast. There would in fact be a gradual succession of the beds deposited as we trace them from Peterhead back to Aberdeen, Stonehaven, Montrose, and Errol, while that near Benlomond would probably be the latest of all.

As these marine beds have suffered much denudation from a subsequent advance of the glaciers and other causes, the upper strata are probably wanting, and we have a blank in the evidence at the next stage. Here may have occurred a long interval of time during which one of those warmer periods intervened when some of the Mammalia flourished whose remains are found in the caves and river-beds of England.

7. Northern Limit of the Red Clay and of the Ice-flow.

Blue clay of the Banffshire coast.

During the extension of the ice along the coast it is probable that it underwent phases of increase and diminution, like all existing glaciers. We are apt to take too narrow and simple a view of the changes that have happened during the long periods these operations of nature embrace. In some of the deeper sections near Peterhead there are indications of considerable variety in the character of the clay. Beds of a fine dark-blue clay occur interstratified with the red, which imply derivation from a different source. Round the northern extremity of Aberdeenshire and along the coast of Banff there is a deposit of this blackish-blue or indigo-coloured clay, which seems to have been derived from the dark slaty rocks of the Banffshire district, and has been carried eastward round the projecting corner of Aberdeenshire until it met the red clay in the district between Peterhead and Fraserburgh.

The ice of the Moray Firth seems to have flowed eastward along the Banffshire coast and turned round the corner of Aberdeenshire at Fraserburgh, where the rocks are glaciated from the north-west; so that there seem to have been two streams of ice—one coming along the coast from the Moray Firth, bringing with it the blue mud

the other coming northward along the coast from Stonehaven, bringing the red mud, and both meeting a little to the north of Peterhead.

The eastward flow of the Moray-Firth ice across the northern border of Aberdeenshire is further proved by the general direction of the transport of boulders in that quarter, as I hope to show more fully in a subsequent paper.

At the town of Aberdeen the Red Clay is associated with beds of fine pale ashy-grey clay; and there is also some of a dun colour, which may have arisen from the mingling of the two sediments. The grey clay has probably been derived from the liquid mud proceeding from the glacier of the Dee valley. The chief mass of this fine grey clay seems to lie below the red; but in some cuttings the two are interlaminated. Details of sections will be found in the Quart. Journ. Geol. Soc. for Nov. 1858, vol. xiv. p. 509.

In the district of Slains and Cruden, between the river Ythan and Peterhead, the clay is widely spread and the red colour strongly marked.

I ought to have mentioned that small pieces of what appears to be chalk, often glacially marked, are not uncommon in the clay-pit at Dryleys * near Montrose, and also at the Black-dog pit at Belhelvie on the Aberdeenshire coast. I have likewise found them, but more rarely, at Invernettie near Peterhead. Small pieces of coal also occur both at Dryleys and Belhelvie.

8. Direction of the Ice-flow to the South of Stonehaven.

Mr. Irvine, of the Geological Survey, has observed marks of glaciation on the coast at a place called the Crawton, a few miles south of Stonehaven, in a direction from S.W. to N.E.; and in an old notebook of my own I find an entry of having seen ice-marks on trap rock near the mouth of the north Esk, not far from Montrose, running from S.W. to N.E., and covered by a thick mass of coarse pebbly red clay. On the Old Red Conglomerate of the Garvock hills, which form a low ridge parallel to the coast in the southern part of Kincardineshire, Dr. Simpson of Mary Kirk many years ago showed me some good instances of glaciation. The direction was about due E. and W., crossing the chain obliquely. This is not the direction in which we should expect land-ice to have moved in that quarter if unobstructed; for the general slope of the country from the Grampians to the sea is from N.W. to S.E. But if the ice was diverted northward along the coast, it is just what might be looked for, as there would be a point where the ice in curving round from N.W. to S.W. would move due E.; and Dr. Howden of Montrose states that the general run of the glacial markings in that quarter is from W. to E.

The features of the sea-bottom along this north-eastern part of Scotland seem to bear some testimony to the former flow of a stream of ice parallel to the coast. There is a submarine bank of elevated

* An interesting account of the superficial beds of clay &c. at Montrose, by Dr. Howden, will be found in the Trans. of the Edin. Geol. Soc. for 1868.

ground called '*the Long Forties*,' which extends from opposite the Firth of Tay in a N.E. direction to opposite Kinnaird's Head. Between this bank and the present coast-line there is a long hollow called "*the Buchan deeps*," which stretches in a parallel line from near Montrose to opposite Kinnaird's Head, deepening very gradually from south to north. This hollow may represent the central path of the ice-stream which grazed the Aberdeenshire coast, while the Long Forties may mark its eastern flank.

9. Reappearance of the Glaciers, and Denudation of the Red Clay.

There is evidence that at some period after the Red Clay had been laid down, the glaciers from the interior again advanced and swept most of it away along the track of the principal ice-streams. In the valley of the Dee the ice came down from the mountains to the present line of coast, and, uniting probably with that of the Don valley, presented a front at least five miles broad, leaving great mounds of gravel and stones all along its margin (*see map*, p. 161). This moraine-gravel distinctly overlies the Red Clay at its termination. The clay is entirely absent from the valleys both of the Dee and Don, only a few small deep-lying patches being left near the town of Aberdeen; while immediately to the north of these moraines, on the coast at Belhelvie, the red clay begins at once to reappear exactly where the gravel ceases, covering the fields beyond the Burn of Milden to the height of 200 feet or more above the sea; and along the south bank of that streamlet the superposition of the moraine gravel upon the wasted margin of the clay can be clearly made out. This gravel also occasionally contains wasted lumps of the clay, and confused masses of the silty beds are sometimes jumbled up with it, as at the north side of the Bay of Nigg near Aberdeen. The morainic character of the gravel is very well seen at the top of the mud cliff at the south side of the same bay (fig. 3, p. 175).

Owing to this new advance of the glaciers, which no doubt coincided with the return of a more rigorous climate, the marine beds have been much destroyed. In many places they have been entirely removed; in others the upper portion has been swept off, or converted into an unstratified pebbly mud; while in others, again, they have been pushed out of place or their stratification has been contorted and more or less deranged by the pressure of the ice. The probability therefore is that the uppermost or last-deposited portion of these marine beds is everywhere gone.

10. Upper Limit of the Submergence.

The upper limit of the submergence during which the Red Clay was deposited cannot at present be determined. The readvance of the ice has blotted out the evidence. The clay itself with a well-defined character ranges up to at least 300 feet above the sea in the Ellon district, being found stretching continuously up to the top of some eminences at that elevation on the estate of Kinmuck and

elsewhere; and as it is a deposit of still water, the probability is that the summit of these eminences lay so deep as to be beyond the agitation of surface waves. On the southern slope of the Hill of Dudwick in the same neighbourhood there is a bed of hard reddish-brown or ferruginous-coloured clay, containing small stones, which covers the quartzite of that hill and thins out on the brow of the eminence at an altitude of 500 feet or a little more. This coarse clay may very possibly have been derived from the same deposit as the finer red clay at lower levels; but of this I cannot be certain.

In this eastern part of Aberdeenshire there are some shoals of waterworn pebbles of quartz and flint on the tops of hills at heights of from 350 to 470 feet, unlike any thing I have met with in other parts of Scotland. Some account of them will be found in the Quart. Journ. Geol. Soc. Nov. 1858, vol. xiv. p. 528. The pebbles are intensely water-rolled, like those of a beach, as if they had been exposed to the action of waves in shoal water; they do not seem to be moraine gravels; and in one place I got fragments of sea-shells at an altitude of about 300 feet. This was in a bed of smaller gravel forming the crest of an eminence 356 feet above the sea, called the Hill of Auchleuchries. It lies quite near to Dudwick, and is 20 miles to the north of Aberdeen and 7 miles from the coast. The species found were:—*Astarte borealis*, several fragments; *A. elliptica* (?), fragment, but rather imperfect for fair determination; *Buccinum undatum* (?), fragments of the spire of a good-sized univalve, probably this species; *Cardium*, 2 pieces, apparently *C. echinatum*; *Cyprina islandica*, a great many fragments; *Mactra elliptica*, a hinge-fragment; *Murex erinaceus*, one specimen, nearly perfect, but a good deal worn, length $\frac{7}{8}$ inch; *Nassa incrassata*, one specimen, nearly whole; *Purpura lapillus*, two specimens nearly entire and a fragment of another; some fragments of *Saxicava rugosa* and *Tellina balthica*; *Tellina calcarea*, some fragments apparently of this species, but too imperfect for certainty; *Trophon clathratus*, one small specimen, imperfect; *Turritella terebra*, one fragment.

It is rather singular to find *Murex erinaceus* here, the only other instance of its occurrence in the glacial beds of Scotland, so far as I am aware, being at Dalmuir in the Clyde district. It occurs, however, on Moel Tryfan.

Although these shoals of waterworn pebbles have not been observed by me above an altitude of about 470 feet, yet over the top of the Hill of Dudwick a few of the very same waterworn pebbles of quartz and flint occur scattered here and there up to a height of 560 feet; and some of these show marks of glacial action which must have been imprinted on them after they were water-rolled. The probability, therefore, is that the shingle beds had originally ranged up to the top of this hill, but had been subsequently removed by glacial action. This would bring the submergence to at least 560 feet, beyond which the evidence fails us.

Quite recently a small denuded patch of fine silt containing shallow-water shells *in situ* has been found by Mr. James Fraser,

C.E., Inverness, at Clava in the valley of the Nairn, at an altitude of 500 feet, which shows that a similar amountof submergence must have taken place in that district.

11. Geological Date of the Submergence.

We have seen that the Red Clay was laid down before the last great advance of the glaciers, and that the submergence to which it is due followed upon a previous development of the ice of far greater amount. This earlier glaciation seems to have been extremely intense and long-continued; for it has well nigh effaced all pre-existing records which would have thrown light upon the antecedent history of the surface. How long it endured, and whether there were other periods of glaciation before it with intervals of milder climate, as some suppose, are questions to which no satisfactory answer has as yet been got from the evidence in this part of Scotland.

The Mollusca whose shells are found in the clay all belong to existing species now living in the Northern seas; and in this respect they resemble those got in the other arctic shell-beds of the East of Scotland, and differ as a group from those found in the Bridlington shell-bed of the Yorkshire coast, and also from those reported by Mr. S. V. Wood from what he terms the Middle Glacial Sands of England, both of which contain some species that are extinct, or at all events unknown in the Northern or British seas. Our submergence must therefore be of later date. The Aberdeenshire group seems more allied to those reported by Mr. Prestwich from the Kelsea-Hill Gravel in Yorkshire (see Quart. Journ. Geol. Soc. for April 1861, vol. xvii. p. 446), and to the shells from the Glacial clays of Lancashire.

Dr. James Geikie, in his recent able work on Prehistoric Europe, has referred the Errol and Montrose clays to a still later period. He terms them Estuarine clays, and supposes them to have been laid down after the last ice sheet had passed away, at a time when he thinks a subsequent submergence of the Scottish coast took place to the extent of 90 feet. I cannot say that I have found any evidence on the Aberdeenshire coast of a subsequent submergence to this extent; and it seems to me that the groups of shells found both at Errol and Montrose infer both an earlier date and a much greater amount of submergence. The Mollusca are a deep-water group, and not an estuarine assemblage. The Errol shell-bed at present lies 40 feet above the sea. A submergence of 90 feet would therefore place it under 50 feet of water, which is little more than 8 fathoms. Now this does not at all harmonize with the character of the group. The Rev. Mr. Brown (who had the assistance of Dr. Otto Torell in regard to the shells), in his paper on the subject in the Trans. of the Roy. Soc. of Edin. vol. xxiv. p. 630, concludes that "the level of the land was at least 150 to 200 feet lower than now;" and, so far as I can form an opinion from the organic evidence, I should say the probability is in favour of a

greater amount of submergence rather than a less. Had they been estuary clays these beds should have contained characteristic estuary shells, such as *Littorina litorea* and *L. rudis*, *Cardium edule*, *Mytilus edulis*, *Scrobicularia*, &c., all of which are wanting; and so are even the more characteristic shells of shallow-sea water, such as *Tellina balthica*. The group is also intensely arctic, more so in fact than those reported from any other part of Scotland, and is just such a lot as might be dredged in pretty deep water on the coast of Spitzbergen at the present day. This intensely arctic character was particularly remarked by Dr. Torell, and affords another good reason why the submergence should not be attributed to a period so late as that to which Dr. Geikie refers it.

I am of opinion therefore that the shell-beds of the red clay at Errol and Montrose belong to the same epoch of submergence as the Red Clay of the Aberdeenshire coast, and that they are not estuarine, but deep-water beds belonging to a period antecedent to the last great advance of the glaciers. Although no bed of Boulder-clay overlies the Errol shell-bed, yet the latter seems to be a mere denuded patch; and the same remark will apply to that of Montrose and of Elie in Fife. Had these clays been laid down in estuaries after the glaciers finally passed away, we might expect to find them more widely distributed at levels beneath 90 feet, whereas they appear to have been much wasted, and occur only here and there in patches, and range up to heights above 90 feet.

I mentioned that some remains of starfishes were got in the clay of Aberdeenshire; but the species was not determined. Probably they were the same as those got at Montrose, St. Andrews, and Dunbar, which have all been referred to *Ophiolepis gracilis* of Allman. At Montrose they appear to be confined to a thin seam of dark micaceous sand, in which they are occasionally pretty numerous. At St. Andrews they also occur in a thin seam of sand in the brick clay at Seafield (see R. Walker in the 'Scottish Naturalist' for April 1875). This thin layer of sand with *Ophiolepis* may very likely mark a definite horizon in the clay all along the east coast from Dunbar to Aberdeen. Dr. Howden of Montrose says that when first exposed this micaceous sand had a strong sulphurous smell as of putrid animal matter.

Although a few skeletons of the whale have occurred in "THE CARSE" or post-glacial estuary mud of the Forth, I am not aware of any remains of this animal having been got in the earlier glacial clays of Scotland—which is rather curious, seeing that bones of the seal have been met with in several cases.

The features of the Aberdeenshire coast which I have described in the foregoing pages seem interesting:—

1st. From the evidence afforded of a movement of ice flowing northward along the coast.

2nd. From the close connexion which is evinced between the presence of the ice and the submergence of the land.

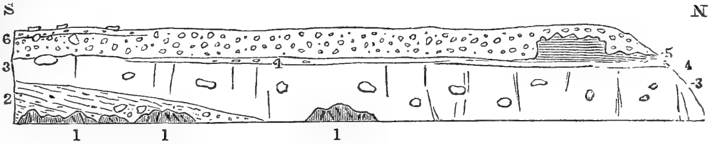
3rd. From the evidence at Aberdeen which shows that the glaciers had again advanced to the coast after the submergence during which the Red Clay was laid down.

The section which is so well exposed in the mud cliff facing the sea at the south side of the Bay of Nigg (fig. 3) is so instructive as to merit a detailed description.

12. Explanation of the Section at the Bay of Nigg.

Fig. 3.—*Section of Mud Cliff at Bay of Nigg.*

(Depth of section about 60 feet; length of do. about 200 yards.)



1. Gneiss. 2. Gravel. 3. Grey Boulder-clay.
4. Red Boulder-clay. 5. Sandy silt. 6. Moraine gravel.

1. The rock at the base is a coarse granitic gneiss not much exposed, and, so far as I can see, exhibiting no clear marks of glaciation.

2. The lower gravel is a very unusual feature in this quarter, as it is seldom that any thing is found between the rock and the grey Boulder-clay above it. This gravel is seen only at the south end of the section. Where it commences at the base of the cliff it is very coarse, with a few large boulders of granite and gneiss from 3 to 5½ feet in diameter; but as it rises and thickens in the bank it ceases to contain any large boulders, and consists of waterworn pebbly gravel and sand, the stones being well rounded; in mineral quality, they consist of granite and gneiss, similar to what occur in the grey Boulder-clay above. This lower gravel cannot be traced for any great length beyond the section, the rocks along the coast to the southward being covered by Boulder-clay. I could see no trace of shells in this gravel, which reaches a thickness of from 10 to 20 feet at its southern extremity.

3. The Boulder-clay which forms the chief mass of the section is of a dull grey or dun colour, is very compact, firm and difficult to pierce, stands up like a wall with a perpendicular or even overhanging front 30 or 40 feet high, although washed at the base by the surf at high tide. At the south end of the section it thins off considerably and rests on the gravel no. 2. In one place, near the middle of the section, it rests on a small knob of gneiss; but further north its bottom is not exposed. It is quite unstratified, very tough and solid, as if it had been compressed beneath a heavy weight, and contains no broken shells or organic remains of any kind, so far as I could perceive. The stones in it are of granite and gneiss of several varieties, with some of quartz-rock, hornblende-schist, felspar-porphyry, and greenstone, the last not common. These stones have their angles worn off, and are generally of small sizes; but some large boulders from 3 to 4 feet in diameter occur here and there in all parts of the mass; and still larger ones are seen at low water along the base of the cliff, which have no doubt been

derived from the gradual waste of the bank. Few of the stones show glacial scratches, which may be owing to their hard crystalline quality in a great measure. This Boulder-clay consists of a fine impalpable mud, mixed with small gritty particles of quartz and felspar, and stones of all shapes and sizes, stuck in all manner of positions, the whole forming a dense impenetrable mass like concrete. The fineness of the mud, which is as fine as flour, makes it adhere tenaciously to the stones like plaster. The included stones are such as might be got from the rocks along the valley of the Dee, of which the Bay of Nigg forms the natural termination; and this grey Boulder-clay is, no doubt, the mud accumulated beneath the glacier which descended that valley.

4. At the top of this grey mud there is, in some parts of the section, a variable amount of reddish Boulder-clay (no. 4), which contains round pebbles of brownish quartz with a reddish exterior, such as occur in the Old Red Sandstone conglomerate, and bits of volcanic rock and jasper, like what are found in the red clay of the Aberdeenshire coast further north. This reddish portion is seen at the middle of the section and towards the north end; and the water trickling down from it imparts a red tinge to the surface of the grey clay beneath. So far as my observation goes, none of these Old Red Sandstone pebbles nor fragments of the same volcanic rocks occur in the deep mass of grey clay; they seem confined to this red portion at the top, which evidently represents the red Boulder-clay of the quarry section at the Cove (fig. 2). Red Boulder-clay containing the same mineral débris and bits of sandstone is seen covering the surface of the rock at the first railway-cutting to the south of the Bay of Nigg, close beside the mud cliff I am describing, the grey clay being absent. This red portion, no. 4, with its distinct colour and peculiar mineral contents, clearly betokens a change of conditions, with transport of material from a different quarter from that of the grey clay.

5. At the north end of the section there is a denuded patch of fine brownish sandy silt, free from stones and containing apparently some seams of reddish silty clay; but I could see no pure mass of red clay in it, and the whole is so soft and sandy that the swallows have pierced it with many of their nesting-holes. It has been cut down in a very irregular manner by the overlying gravel, which envelops it quite unconformably; and its stratification is in some places bent and twisted. Its structure indicates deposition from water; and as it differs much from the stuff both above and beneath, it must have been formed under very different conditions. It may be a remnant of marine silt deposited during the period of submergence, when the beds of fine clay were laid down along the coast.

6. The upper gravel is a very coarse jumble of stones, pebbles, and sand, without any regular arrangement. The materials of which it consists range in size from sand and pebbles up to blocks and boulders 3 or 4 feet in diameter. There are masses of shattered rock débris, such as might be found at the base of a weathered cliff of gneiss; and there are here and there patches of

bedded gravel and sand very irregularly placed. This upper coarse gravel varies in thickness from 15 to 20 or 25 feet, and is coarsest in quality towards the south end of the section, where a distinction is observable in it, the uppermost three or four feet consisting of angular stones and chips of granite and gneiss of all sizes, sticking in all manner of positions in a matrix of ferruginous muddy sand; while large boulders of the same kinds of rock are imbedded in the surface, back from the edge of the bank. Below this the gravel is of a looser texture, but still very coarse and full of large stones. Some of the stones in it are rounded as if water-rolled; and in this lower portion I here noticed some wasted lumps and nodules of red clay, likewise some of the reddish quartz pebbles which appear to have come from the Old Red Sandstone conglomerate. At the very bottom, where it meets the grey Boulder-clay at the south end of the section, there is a seam of finer gravel 3 or 4 inches thick.

This upper gravel or mass of stony rubbish has all the appearance of being a morainic accumulation. It has none of the features of a raised beach, and seems to contain no trace of marine shells or other organic remains. It ranges over the adjacent heathy ridge of high ground called the Hill of Nigg, where the morainic character of the heaps of stones and boulders is very marked. Its position in the section, and the fact of its containing lumps of the red clay, show it to be of later origin than that deposit. This harmonizes with the evidence we find at Belhelvie, and proves that, after the transport of the red stuff from the south, the glacier of the Dee again came down to the coast and played havoc amongst the clay beds that lay in its road.

Note to the Map (p. 161).

The map shows approximately the area in which the Red Clay is met with. In some places outlying patches may be found a little beyond the limits I have assigned to it, showing that at one time it covered a larger extent of ground. It must also be understood that the clay does not cover all the tract coloured red, there being many places in which it is either wanting or hidden by overlying masses of more recent origin. Along the Kincardineshire coast, between Aberdeen and Stonehaven, it does not seem to extend far inland, and is generally of a coarse pebbly nature like a Boulder-clay, occurring in patches on the high rocky ground which borders the sea, but stretching further inland near Stonehaven.

17. *On an Extinct Chelonian Reptile* (Notochelys costata, Owen), *from* Australia. By Prof. Owen, C.B., F.R.S., F.G.S., &c. (Read January 25, 1882.)

Order CHELONIA.

Genus Notochelys *.

Species Notochelys costata.

Hitherto the fossil reptilian remains transmitted to me for description from Australia have been limited to parts of the skeleton of the great horned Lacertian (*Megalania prisca*, Ow. †).

The first evidence of a Chelonian from that continent was sent in the present year (1881), by our fellow Member Professor Archibald Liversidge, of the University of Sydney, New South Wales. He kindly permitted a mould to be taken of the specimen, with the request that the original should be returned to him after a description and figure had appeared. The mould and casts are in the British Museum, Cromwell Road.

The specimen was found in a formation at Flinders River, Queensland; but the nature and age of the deposit are not stated. It is petrified and, with the imbedding matrix, of great weight.

The fossil consists of an anterior portion of the carapace (fig. 1) and of the plastron (fig. 2) brought into unnaturally close contact by posthumous pressure.

The carapace includes the four anterior and part of the fifth neural plates (fig. 1, *s* 1, 2, 3, 4, 5), and the second, third, fourth and expanded portion of the first costal plates of the left side (ib. *pl* 1′, 2′, 3′, 4′); of the proximal or expanded portions of the right second, third, and fourth costal plates (ib. *pl.* 2, 3, 4,) with a fragment of the first (*pl.* 1 *r*); a portion of the left half of the nuchal plate (*ch*); and portions of the first and second marginal plates of the left side (*m* 1, *m* 2).

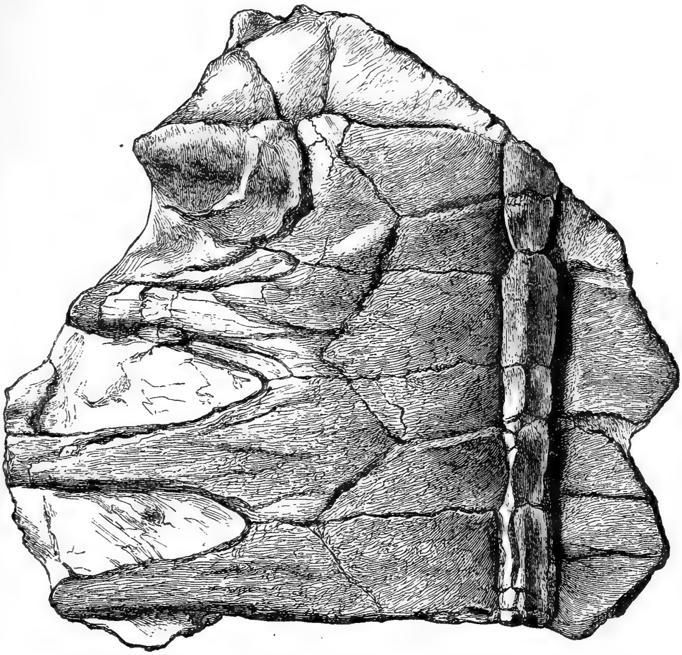
The preserved part of the plastron includes the right and left coalesced hyo- and hyposternals (fig. 2, *hps*, *r*, and *hps*, *l*), indications of the episternals and the entosternal; and, anterior to these parts of the plastron, both scapulo-acromial bones (51) have been brought into view.

The first neural plate (fig. 1, *s* 1), 1 inch 10 lines long by 9 lines broad, has a small portion of the left antero-lateral angle preserved with the rest of the plate: this slightly decreases in breadth toward the hinder junction with the second neural (*s* 2). The impression of the transverse junction of the first vertebral scute (*v* 1), with the second (*v* 2), crosses the plate *s* 1 near its mid length.

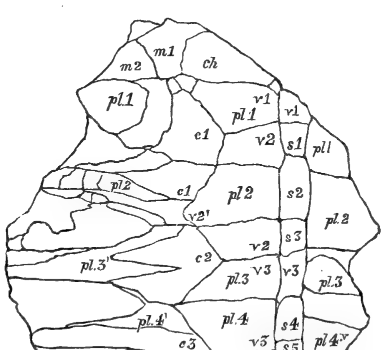
* νότος, south, χέλυς, tortoise.

† Phil. Trans. for the years 1858, 1880 and 1881.

Fig. 1.—*Anterior Portion of the Carapace of* Notochelys costata ($\frac{1}{4}$ nat. size).



Outline index to the above.



The first costal plate (*pl.* 1) articulates with the entire lateral border of the first neural plate, extends a little in advance of that to articulate with the nuchal plate (*ch*), and also a little beyond the posterior border to join the truncated anterior angle of the second

neural (*s* 2). In this character *Notochelys* differs from *Chelone longiceps* *, and agrees with *Chelone breviceps* †.

Only the mesial expanded portion of the first costal (*pl* 1), which articulates also with the nuchal (*ch*) and second costal plates, is preserved; its fore border joins the second marginal plate (*m* 2); the lateral anterior angle also articulates with the first marginal plate (*m* 1). Fractured parts of the narrower rib-like outward extension of the first costal (*pl* 1) are preserved, indicating a length of the entire plate of 5 inches. The breadth of the expanded portion exceeds that of the same part in the succeeding costal plates.

The second neural plate (ib. *s* 2), of greater breadth than the first, has the anterior costal plate (*pl* 1) articulated with the anterior truncated angle. The posterior angles of the second neural are also truncated, but in a minor degree, for articulation with the third costal plate (*pl* 3), in which character it differs from the Eocene Chelonians figured in the under-cited work, some of which, e. g. *Chelone longiceps*, *Ch. subcristata*, *Ch. convexa*, show the second vertebral plate (*s* 2) articulating with the second costal exclusively; others (e.g. *Chelone breviceps* and *Ch. subcarinata*) articulate, as in the existing *Chelone mydas*, with a portion of the second costal, but not with any part of the third costal plate.

The third neural plate (ib. *s* 3) has marginal articulations exclusively with the third costal plate (*pl* 3), and neither the fore nor the hind angles are truncated. In *Chelone subcarinata* ‡ the third neural plate articulates with both the second and third costal plates; and in *Ch. breviceps*, in a larger proportion with the second costal—the third vertebral plate here presenting a hexagonal figure, while in the present species it is a parallelogram. Its length, in *Notochelys*, is 1 inch 8 lines, its breadth 9 lines; it is crossed transversely a little in advance of its mid length by the line of junction of the second to the third vertebral scutes (*v* 2, *v* 3).

The fourth neural plate (ib. *s* 4), with a broader anterior border than the third (*s* 3), shows the anterior truncated angles of that border articulating with the third costal plate; the long lateral borders articulate exclusively with the fourth costal (*pl* 4). But a small portion only of the fifth neural plate (*s* 5) is preserved.

The second costal plate (*pl* 2) is larger, but antero-posteriorly narrower than the first. The extent of the posterior suture with the third costal, 2 inches 9 lines, gives that of the expanded part of the plate: beyond the suture it begins to contract to the ordinary rib-like proportions, the preserved extent of which free part is 3 inches. The expanded part is impressed with the lateral angle of the second vertebral scute, from which is extended the impression of part of the junction of the first costal (*c* 1), with the second costal (*c* 2) scutes.

The third costal plate (*pl* 3) has similar proportions of the expanded and rib-like parts to those of the second costal. It articulates mesially with the third neural and the anterior angle of the broader

* Hist. of British Fossil Reptiles (4to, 1849), plate 13. fig. 1.

† *Ib.* plate 10.

‡ *Ib.* plate 10.

fourth neural. It is impressed by the entering angle of the junction of the second costal scute (*c* 2) with the second and third vertebral scutes (*v* 2, *v* 3). The length of the rib-like production of the third costal scute from the suture with the second costal is 3 inches 10 lines; the entire length of the plate is 6 inches 9 lines.

The entire extent of the free portion of the fourth costal plate (*pl* 4) appears to be preserved; and its length from the suture with the third costal is the same as in the third: there may be a small terminal portion wanting in both; the breadth and length of the expanded portion seem to have been the same as in *pl* 3; but the fracture of the hind part of the specimen may have removed that margin of the fourth costal.

This plate shows the impression of the lateral angle of the third vertebral scute (*v* 3) at its junction with parts of the second and third costal scutes (*c* 2, *c* 3).

Of the costal plates of the right side, parts of the expanded portions only are preserved; and they have been partially dislocated from the vertebral plates by pressure from above; only small angular portions of the 1st and 4th are present.

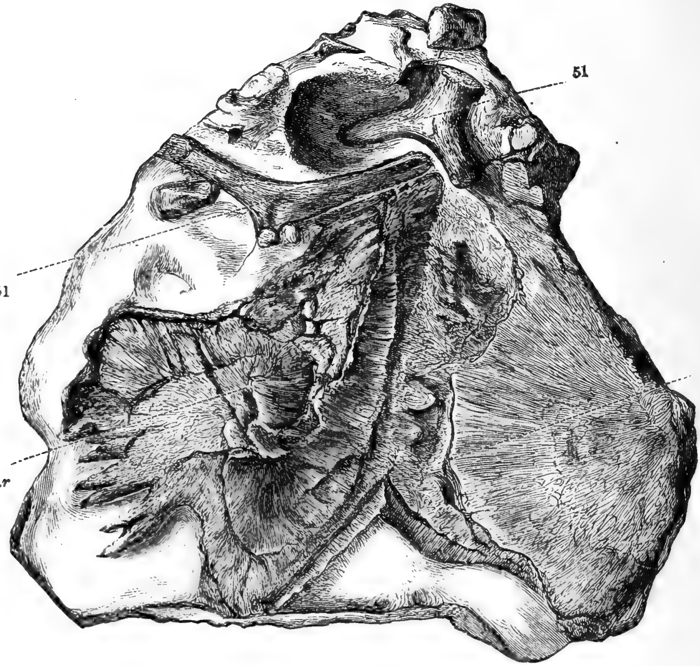
Not more of the nuchal plate (ib. *ch*) is preserved than serves to indicate that the mesial part of its hind border is slightly produced backward to unite with the first neural plate; the rest of the hind border, preserved only on the left side, unites suturally with the fore border of the expanded part of the first costal plate. Laterally the nuchal plate unites with the foremost of the marginal plates (*m* 1); and to this is attached a portion of the second marginal plate.

The breadth of the entire carapace of *Notochelys costata*, taken across the fourth pair of the costal plates, the right plate being restored, is 14 inches. Assuming that about half of the length of the carapace is shown in the fossil, the total length may be estimated at 20 inches.

Of the plastron are preserved the right hyo-hyposternals (fig. 2, p. 182, *hps. r*) and a great proportion of the left (ib. *hps. l*). They appear to have been in contact mesially for rather more than the anterior half of their fore-and-aft extent: the postero-mesial borders diverge at almost a right angle from the mid line. The best-preserved hyo-hyposternal rapidly loses in length as it extends outwards for above two thirds of its total breadth; then it again expands to less than half the mesial length, and terminates in diverging pointed rays, of which the hindmost are longest and narrowest; two of these are bifurcate. They do not appear to have effected any bony union with the costal elements of the carapace.

The left hyo-hyposternal shows the best-preserved mesial border, the anterior portion of which seems to have underlapped the corresponding border of the right bone. The underlapping portion shows two large angular processes, each an inch broad at the base, and contracting to a point; they are followed by a series of six or seven smaller processes diminishing in size as they recede in position.

Fig. 2.—*Anterior Portion of the Plastron of* Notochelys costata ($\frac{1}{4}$ nat. size).



In both elements of the plastron the exposed surface has lost some substance near the mesial margin. Sufficient, however, remains to throw welcome light on the affinities of this Chelonite.

The characters of the carapace might be interpreted as those of a true Turtle (*Chelone*) not modified sufficiently to bear a subgeneric distinction. But those of the plastron show the well-marked characters of the part in *Trionyx* and *Chelys*; the hyosternal and hyposternal, which are separated by a persistent transverse suture in *Chelone* as in *Emys* and *Testudo*, have coalesced, and so completely in *Notochelys* as to leave no trace of the original presence of the suture in the immature reptile. The hyosternal element in Chelonians where the plastron is best ossified, as in the extinct Eocene kinds, does not extend backward beyond the second vertebral scute on the fourth neural plate *; whereas the single plastral bones (fig. 2, *hps*), extend backward beyond the third vertebral scute (fig. 1, *v* 3), and probably beyond the fifth neural plate; for the hindmost angles of both plastral bones have suffered fracture. Sufficient is preserved, laterally, to show that the carapace and plastron were not united

* Compare Hist. of Brit. Foss. Rept. pl. 1 (*Chelone breviceps*), pl. 13 (*Chelone longiceps*), pl. 14 (*Chelone convexa*). See also Cuvier, Ossemens Fossiles, tom. v. pt. ii. (4to, 1824) pl. xiii. fig. 6 (*Chelone mydas*), fig. 7 (*Chelone caretta*).

together by bone; consequently the freshwater (Emydian) and terrestrial (Testudinarian) groups of *Chelonia* are out of the pale of comparison. In the absence of the alternate broadening and narrowing of the mesial and lateral ends of the costal plates also *Notochelys* differs from the foregoing groups, and resembles both the *Chelydes*, *Trionyces* and *Chelones*.

The impressed indications, however, of the size and shape of the vertebral (*v* 1, 2, 3) and costal (*pl* 1, 2, 3, 4) scutes remove the present Chelonite from the family of soft Turtles (*Trionycidæ*), and manifest its affinity to the Chelydians. But a comparison of the characters shown in the preserved portion of the bony cuirass indicates differences which have generic value.

These modifications, especially of the carapace, show a nearer affinity to the marine Turtles (*Chelone*) than the known Chelydians exhibit, and indicate a more generalized type in the Australian fossil. This adds to the interest with which we hope to hear of the precise geological position of the bed, which, with its included fossil, has undergone such complete petrifaction.

I have only to add that the open angle between the scapula and its connate and elongate acromial process (fig. 2, 51) more resembles that in *Chelone caretta* than in any existing species of *Chelys* or *Trionyx*.

The details necessitated for determination of the extinct Chelonians of our Eocene formations (Hist. of Brit. Foss. Reptiles, vol. i.) have led me to note characteristics of my present subject in aid of the comparisons which our Australian fellow workers may have to institute with respect to subsequently discovered fossil remains of *Chelonia* in their continent.

Discussion.

Prof. Seeley regretted that the specimen upon which the paper was founded was not upon the table. It would also have been helpful if the author had attempted a restoration. He pointed out how much the elements of the plastron must have been displaced. He could not help suggesting that the hyo-hyposternal bones were not combined, but that those preserved were the hyosternal bones only. If this were possible, he doubted the propriety of the name *Notochelys*, as, if the above point were not proved, there was nothing to separate the genus from *Chelone*. Had the peculiar modification of the plastron supposed by the author existed, he should have expected more marked differences in the carapace. At the same time the value of the contribution could not be doubted.

18. *Additional Discoveries of* High-level Marine Drifts *in* North Wales, *with Remarks on* Driftless Areas. By D. Mackintosh, Esq., F.G.S.* (Read February 22, 1882.)

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I. Introductory Remarks.

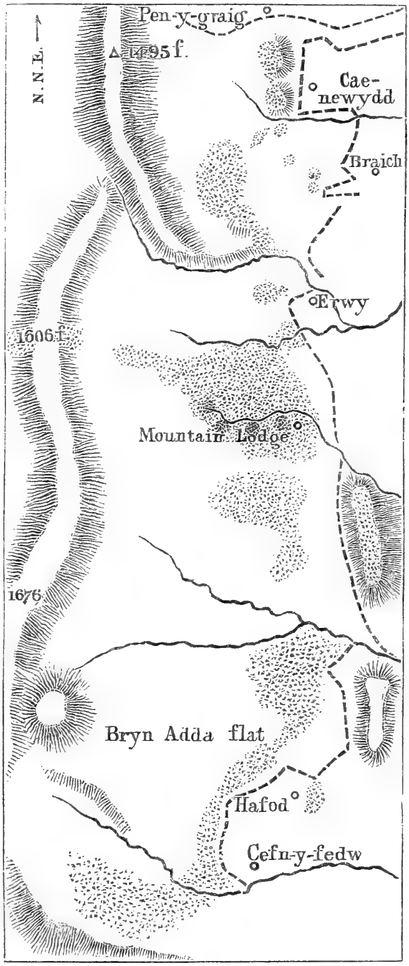
Since commencing this branch of geological research, I have found the subject increasingly beset with difficulties, which have chiefly arisen from the necessity for exploring new ground at the risk of being frequently disappointed. Since my last paper † was written, I have not succeeded in discovering any very decided traces of high-level marine drifts in *entirely* new localities; and though some may have escaped my notice, there can, I believe, be little doubt that the drift-zone between Minera and Llangollen Vale contains such an immense development of undoubted sea-beach deposits, compared with other districts, as to render it worthy of a more detailed description than that contained in my last paper, more especially since I have succeeded in tracing its extension southwards over an additional two miles (see Map, fig. 1). The total absence, so far as yet known, of marine drifts or raised sea-beaches above an altitude of 800 feet higher than the present sea-level, in Scotland, continental Europe, Asia, or North America ‡, ought to be regarded as investing the above drift-zone (which ranges between 1000 feet and 1350 feet above the sea) with an additional interest.

* In these discoveries I was aided by the Committee of the Government Fund for Scientific Research.

† Quart. Journ. Geol. Soc. for August 1881, p. 351. In line 19 from the bottom of p. 352, for "rounded" read pounded, which was the term applied by Darwin to the condition of the slate fragments on Moel Tryfan. During my last visit to this mountain, in nearly all the sections then exposed, I saw a layer of slate-chips several feet in thickness, which rested on the edges of the nearly vertical slates *in situ*. The chips, where they could be seen in *profile*, inclined (in many places along more or less curved lines) from the N.W. or N.N.W. During this visit one section showed numerous boulders in the clay (above the sand and gravel), some of the largest being on the surface, or only slightly imbedded.

‡ According to Lyell, in his 'Antiquity of Man,' 700 feet is the greatest height reached by shelly drift in North America.

Fig. 1.—*Sketch Map of the Drift-zone between Minera and Llangollen Vale.* (Scale 1 inch to a mile.)



The broken line represents a wall (generally above the 1000-feet contour-line) which separates the cultivated ground on the east from the grass-, heath-, and bog-land on the west. The dotted spaces represent exposures of more or less rounded gravel and sand.

II. Extent of the Drift-zone between Minera and Llangollen Vale.

So far as it is revealed by indications at the surface or in excavations, this zone extends almost continuously from a point south of

Pen-y-graig (S. of Minera) to a point about half a mile W.S.W. of Cefn-y-Fedw farm-house, its extreme length along a line from N.N.E. to S.S.W. being little short of *five miles* (see Map, fig. 1). Its average breadth is probably about one third of a mile, but in some places it reaches three quarters of a mile. It extends in a direction nearly coincident with that of the axial ridge on the eastern slope of which it is situated. The extreme height of this ridge towards the N. end is 1495 feet, and towards its S. end 1677 feet (according to the 6-inch Ordnance map).

III. Detailed Description of the Drift-zone.

Previously to making a more minute survey of this area than on former occasions, I went over the Bryngwyn district immediately north of Minera; but nowhere there, or west of Minera, could I see any stones that were not angular (away from the small river which flows past Minera); and it is a remarkable fact that granite erratics were likewise absent, though this may perhaps be explained by supposing that the district was too deeply submerged to intercept the floating ice which, further south on Minera mountain, left numerous granite erratics. On walking from the lower Park lead-mines S.W. towards the stream called Sychant, and thence in an easterly direction, an enormous rain-rut revealed at least forty feet thickness of angular gravel, with a small percentage of rounded stones, which may either have been accumulated by terrestrial agency, or speedily washed down the slope by the sea to a level below the rounding action of waves, at the time when the sea was depositing the gravel and sand on the E. side of Minera mountain. Near the summit of the mountain the stones were nearly all angular, and continued so until a gentle descent on the E. side of the axial ridge (towards and beyond the upper Park lead-mines) showed a considerable proportion of rounded stones in clay. On the E. side of the flat swampy area a number of small excavations in one of a series of large mounds, 1300 feet above the sea (W. of Higher Wilford), showed decided indications of much rounded gravel and sand. E. of this mound, at about 1200 feet, other excavations showed similar phenomena. W. of Cae-newydd (Cae-mynydd on one-inch map) a mound, about 1200 feet, revealed striking indications of its consisting of rounded gravel and sand; and W. of it, in the sides of a brook-channel, fine gravel might be seen under clay. Further S., in the Frondeg district, and above Braich, is the shelly gravel-pit described in my last paper *, and the gravel-mound higher up. S.W. of the latter there is a large flattish gravel eminence, and in the neighbourhood the flat ground largely consists of rounded stones up to 1350 feet. N. of a stream which passes by Erwy cottage, and about half a mile N.N.W. of that cottage, there is a large gravel mound

* For fear of being accused of exaggerating heights, with the view of supporting theories, I underestimated the altitude of this gravel-pit, which (from a comparison of neighbouring bench-marks) must be at least 1150 feet above the sea. There are several small gravel hillocks at a short distance from it.

with excavations, showing a great extent of well-rounded gravel and sand, at an elevation of 1236 feet; and near to it there is a small gravel hillock. N. of Erwy there are two small gravel hillocks, and W. of them a large knoll with several pits, showing numerous extra rounded stones, and much fine laminated sand, at a height of about 1130 feet. The stream which flows past Cae-llwyd has made a deep excavation in more or less rounded gravel, which extends for a greater or less distance on both sides; but here and elsewhere it is obvious that the gravel was deposited before the present stream began to flow over it and excavate its present channel. The heather-covered moor between here and Mountain Lodge in many places shows signs of being composed of more or less rounded gravel and sand; while E., N., and N.W. of Mountain Lodge there are numerous exposures of rounded gravel from 1010 feet up to 1174 feet (N. of Mountain Lodge). The lodge (about 1100 feet) and its garden are situated on a great thickness of gravel and fine sand (fig. 2). Along the road and its bifurcations N.W. of Mountain Lodge, as high up at least as 1350 feet above the sea, there is much rounded gravel and sand spread over comparatively flat ground, or rising in the form of mounds or hillocks. Near the lodge, on the S. side of the small stream, there are two large gravel-pits now disused; and about 352 yards from the lodge in a N.W. direction, is the gravel-pit, 1230 feet above the

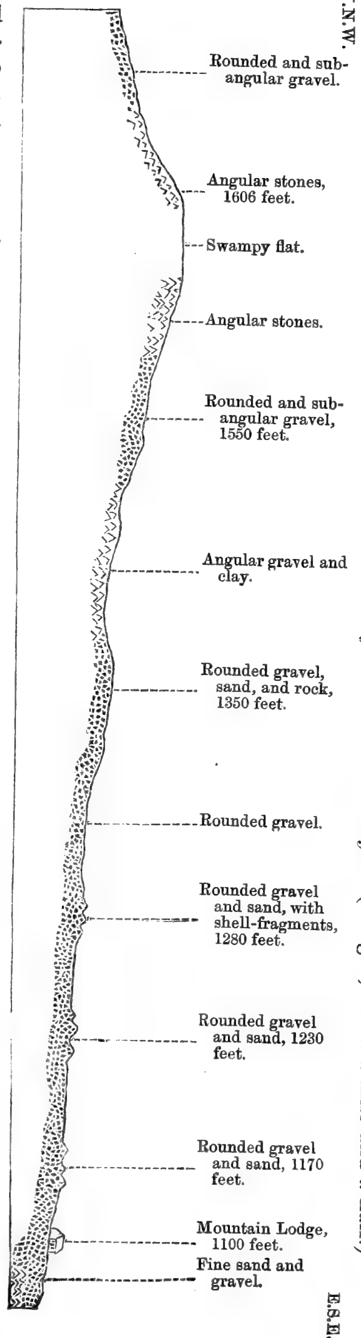


Fig. 2.—Section from Mountain Lodge to the Summit of the Mountain-range. (Length, about a mile and a half.)

sea, mentioned in my last paper. Through a fear of exaggerating heights, I mistook the height of this pit for that of the one higher up, until I paced the ground, the result of my last visit being that the upper pit (in which I found shell-fragments) is at least 1280 feet above the sea. Some distance S. of Mountain Lodge there is a gravel-pit showing very fine sand and rounded stones at the end of a ridge which extends a great distance in a westerly direction. S.E. of Mountain Lodge (as well shown on the 1-inch Ordnance map) there is a ridge about one third of a mile in length, which is very steep on the western side. So far as can be seen, the summit, which rises to 1031 feet, is nearly all covered with rounded gravel. At the south end the gravel is extra rounded, and the sand finely laminated, especially at an elevation of between 900 and 1000 feet. The gravel extends some distance down the southern slope of the hill, having probably been washed down while the land was rising. Lower down the stones are nearly all angular; and this is even the case in the bed of Afon Eitha, which flows in an easterly direction along the southern base of the hill. Here, and elsewhere in the drift-zone under consideration, it is obvious that the streams have not yet had time to round the angular stones with which they have met in their courses, and that where many rounded stones are found in their channels they have been derived from the surrounding marine drift. S.S.W. of Afon Eitha, near Ty Rhywyn, the eastern part of Bryn Adda Flat (see 6-inch Ordnance map) contains many stones more or less rounded. S.W. of Ty Rhywyn a number of small grass-covered swellings of the ground above moss, bog, or clay show indications of being composed of rounded gravel and sand; and the sides of roads and brook-channels show a considerable percentage of rounded stones. E. of Ty Rhywyn the ground in some places undulates in a similar manner to that which further N. has been found to consist of rounded gravel and sand. Between Bryn-Adda cottage and Hafod there is the largest gravel and sand mound to be met with in the whole drift-area. It may be seen from a great distance, and from many points of the compass. Its height above the sea is nearly 1100 feet. The stones are more or less rounded, and the gravel and fine sand stratified *. S.W. of the neighbourhood of Hafod, well-rounded, subangular, and angular stones may be seen along the side of the stone wall which separates the arable from the waste land on the eastern side of the mountain called Cefn-y-fedw on the 1-inch Ordnance map; and many rounded stones may be found W.S.W. of Cefn-y-fedw farmhouse, on the dip slope of the Carboniferous sandstone, up to within a short distance of the brink of the escarpment, where their height above the sea must be at least 1300 feet. It is worthy of remark that below the 1100 contour-line, S.E. of Cefn-y-fedw, the stones down to a considerably lower level are strikingly angular. This furnishes

* Among the stones, *local* Carboniferous sandstone or grit, and quartz or quartzose conglomerate, predominate; but there are also specimens of Wenlock grit and slate from the W. or S., and chert probably from the indirectly local Mountain Limestone.

another evidence of a variation in the rate of submergence, the rounded stones indicating a more protracted sojourn of the sea than the angular stones which, during a rapid subsidence of the land, would soon sink beneath the rounding action of waves and shallow currents (see last paper, Q. J. G. S. for August 1881, p. 364 *). A few Eskdale granite pebbles have found their way as far S. as Bryn Adda flat, S.W. of which I searched for them in vain †.

IV. Probable Origin of Drift-knolls.

Before entering on this subject it may be necessary to state that the drift-area under notice is, in transverse section, a slope consisting of an alternation of flat and undulating ground. There is no appearance of a *terraced* configuration like that of the "raised beaches" of the W. of Scotland, which must have resulted from pauses or intervals of rest between successive upward movements of the land above the sea. It ought likewise to be stated that it is difficult, if not impossible, to make out the precise order of succession of the deposits. In many places the rounded gravel and sand would appear to graduate on the same horizon into clay with angular stones; but in most places it evidently comes under the clay. So far as can be seen in sections, the clay chiefly occupies hollows (excepting in the extensive clay flat between the gravel knolls and the axial ridge), around which it appears to thin out towards the summit of the gravel and sand knolls, where it is only represented by a sprinkling of loam, with local angular stones (including large blocks), which are every year becoming scarcer through being utilized in stone walls. In trying to account for the origin of the knolls, the following possible explanations may be briefly taken into consideration:—

1. *Exposed portions of Gravel and Sand elsewhere concealed under Clay?*—Though at first sight this theory might appear satisfactory, a little consideration will show that it is more a statement of a fact than an explanation, because it does not account for the steep-sidedness of the knolls, or for their frequent occurrence in more or less perched positions.

2. *Heaps of erratic stones precipitated from floating Ice?*—As most of the stones in the knolls are local, or indirectly local, floating ice carrying stones from a *great distance*, and dropping them on breaking up or stranding, would not account for the existence of the knolls, though it is conceivable that *local* floating-ice, on becoming charged with local and previously deposited erratic stones, might have formed at least some of the smaller and irregularly-shaped knolls.

* The semicolon in line 4 from the top, p. 365, should be a comma.

† There are, however, some large Arenig boulders which probably found their way from the W. over the Eglwyseg escarpment. It would appear that the northern drift current (at a height of more than 1000 feet above the present sea-level) must have terminated before reaching as far south as Llangollen Vale, though a few straggling northern erratics may yet possibly be found further south.

3. *Forced up by the grounding of floating Ice?*—It is obvious that floating ice, either local or from a distance, on being intercepted by rising ground, might have forced up previously deposited gravel and sand, and at the same time contributed its load of stones, so as to leave a knoll-shaped elevation *.

4. *Accumulated by currents?*—It is the general belief of geologists that the Irish eskers were piled up by currents in a shallow sea; and the same agency, in all probability, accumulated the mounds of gravel and sand often seen at low levels in the N.W. of England and E. of Wales †. As an *example* of conditions which may have been favourable to accumulation by currents in the area under consideration, it may be stated that when the sea, through the sinking of the land, reached a height of what is now 1250 feet above its present surface-level, its depth must have been about 100 feet at what is now the level of the Frondeg shelly gravel knoll, so as to leave a vertical range of 100 feet for the play of currents along shore or in other directions ‡. In many of the knolls there are clear traces of current-bedding, while the paucity of well-striated stones and of contorted laminæ would seem to militate against the idea of the knolls having been accumulated by the stranding of floating ice. It ought likewise to be remembered that many of the larger knolls (N.W. of Erwy and Mountain Lodge, for instance) are situated in depressions with rising ground on the N. side, or on the side from which the erratic-laden ice must have floated; in other words, they occur in positions in which they might have been left by currents but not by stranding ice.

5. *Reasons why they often occupy Perched Positions.*—Among these reasons may be mentioned the possible tendency of the rising ground on which they now stand (when it was under the sea) to intercept currents and floating ice so as to cause an accumulation of gravel and sand. The perched, or comparatively perched, knolls are chiefly to be found in the Frondeg district towards the north end of Minera Mountain, where it is possible, if not probable, that the large knolls situated W. and N.W. of Cae-newydd (or Cae-mynydd) were accumulated round rocky nuclei. The great Hafod knoll towards the south end of the drift-area may be said to occupy a semi-perched position, the ground only rising from it in a northerly direction §. In concluding this part of the subject it may be remarked that the occurrence of drift-knolls in perched positions is incompatible with the idea of their freshwater origin (even if they

* In the Arctic regions the stranding of floating ice on sea-beaches forces up the shingle into ridges and hummocks.

† Notably around Ellesmere, Shropshire.

‡ It may likewise be remarked that the sea-bed in an easterly direction must then have deepened much more suddenly, and to a much greater extent, than is now the case around the shores of England and Wales. When the sea-level coincided with what is now the 1260 feet contour-line, its depth over the site of the railway between Wrexham and Ruabon must have been nearly 1000 feet.

§ As this knoll is situated on a slope facing the south, it cannot be explained by the stranding of ice.

contained no marine fossils), because fresh water would tend to flow *from*, and not *to*, the rising ground on which they are situated *.

V. Driftless Areas in North Wales.

The term "driftless" (which I have used for the sake of *brevity*) is here intended to apply to those districts in which I have not yet seen any decided instances of *rounded gravel and stratified sand* at levels higher than the 1000 feet contour-line.

1. *South and North of Pont Fadog.*—The discovery of high-level marine drifts on the eastern borders of the Welsh mountains N. of Llangollen Vale naturally excited an expectation that similar drifts might be found S. of the Vale (an expectation, however, which was not realized). On ascending from Pont Fadog (about 3½ miles W. of Chirk railway-station), and walking in a southerly direction over the plateau between the lime-kilns and Gwernydd-gymal †, though the ground in many places was covered with numerous fragments of Silurian and Carboniferous grit and limestone, I could not find a single instance of even an approximately rounded stone or of stratified sand. Several so-called gravel-pits (two of them west of Plâs-crogen) are marked on the 6-inch Ordnance map; but they all consist of perfectly angular stones, and sand arising from the mere disintegration of the sandstone rock *in situ*. From what I saw on former occasions of the westerly continuation of this plateau as far as the New Inn (at the great bend of the river Ceiriog), I have reason to believe that the whole of it, or almost the whole of it, is free from marine drift. Neither have I seen high-level marine drift further south. On ascending the northern slope of the Ceiriog valley, the rounded stones seen at or near to the bottom of the valley speedily disappeared, and none but strikingly angular stones could be found the whole way up to the summit of the ridge, and down the north side, in the direction of Llangollen, until a level of about 400 feet above the sea was reached. Even at that comparatively low level the drift presented a more or less "pell-mell" appearance, though in other parts of the Dee valley, up to a considerable height, well-rounded shingle and stratified sand may be seen ‡.

* It ought likewise to be stated that while the general form of the ground is undoubtedly preglacial, the shape of the drift-knolls presents little or no appearance of having been modified by subaërial agency since the time they were left by the sea. This might be expected, not only from their proximity to the summit of the mountain-ridge, but (in the northern part of the area) from their being on the border of an extensive covering of peat, which absorbs most of the rainfall, the remainder supplying a few small streams which have made channels showing sections of the clay and gravel from 1 to 2 feet in depth. There is reason for believing that in the greater part of the area the denudation is chiefly subterranean, the rain-water finding its way down to the underlying Carboniferous limestone. It is not generally known that under Minera Mountain there is one of the largest (if not the largest) of the subterranean rivers in Britain.

† The average level of the part of the plateau I went over may be about 1150 feet above the sea.

‡ It ought to be stated that large boulders which have been drifted from the Arenig Mountains in an easterly direction are common on the high ground

2. *Ty-Cerrig Area.*—Though I had previously gone over this area many times, I thought it desirable to make sure that it was free from undoubted marine drift. S.W. of Ty-cerrig farm-house (above Berwyn railway station) a series of terraces rise one above another on the northern slope of a hill. From a distance they present a very striking appearance, and might easily be regarded as raised sea-beaches. From late observations, however, I have been led to question their marine origin; for rounded stones are comparatively rare, though they are not altogether absent. It is at the same time difficult to understand how the chemical action of the atmosphere on Silurian shale or grit can have carved out these terraces, seeing that they mainly consist of loam, with many angular stones; while the mechanical action of rain-water could not have arranged the loam and stones in a series of nearly horizontal shelves. At present rain-torrents appear to be chiefly occupied in making transverse breaches in the terraces. In connexion with the main subject of this paper they are worthy of notice on account of their levels roughly corresponding with those of the undoubted sea-margins already described; in other words, they range from about 1100 to 1300 feet above the present sea-level.

3. *Moelfre-uchaf and Frithog Area.*—North of Frondeg (south of Minera), and along the outer slopes of the Welsh mountains as far as the Vale of Clwyd, I have seen no marine drift above the 1000 feet contour-line. There would appear to be a similar absence of high-level marine drift along the outer slopes of the mountains between the Vales of Clwyd and Conway, as well as on the sides of the Vale of Conway. South of Llandulas Moelfre-uchaf rises to 1300 feet; but on its northern slopes and flats, as well as on those of the mountain east of it, and in the pass between the two mountains, I could not find any approach to rounded gravel, though there were numerous fragments of Wenlock grit and shale, which might have been readily rounded by sea-waves. It is likewise worthy of remark that at the lower levels between Moelfre-uchaf and the sea-coast I could see or hear of no very decided instances of well-rounded gravel and stratified sand, excepting on the ridge south of Llandulas railway-station, where Mr. John Price of Chester a short time ago discovered an extensive deposit, with sea-shells, at a height of probably about 500 feet above the sea-level. This deposit I did not see, as I was bent on discovering *high-level* marine drifts. On the plateau east of Llanrwst, called Frithog on the 1-inch Ordnance maps, at heights of between 1000 feet and 1300 feet, I could find very few rounded stones, though in many places there were large expanses of angular débris underlying or horizontally alternating with Boulder-clay. On the opposite or Snowdon side of the Vale of Conway I have seen no decided instance of high-level marine drift, though in the neighbourhood of Llyn-dulyn many blunted or partly rounded stones may be seen in moraine heaps.

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between the valleys of the Ceiriog and the Dee, while in the latter valley they are numerous, and in the former sparingly distributed.

4. *North-central Wales.*—At levels above 1000 feet on the mountain-slopes or plateaux bordering the valley of the Dee, between Llangollen and Bala, I have not yet seen any deposits consisting of well-rounded gravel and stratified sand. The occurrence, however, of such deposits on watersheds nearly, if not quite, 600 feet above the sea, would appear to show that the sea at one time must have been present in the Dee valley. Mr. Ruddy (who is intimately acquainted with the area between Corwen and Bala) informs me that there are several extensive dome-shaped deposits of regularly stratified gravel and sand at an elevation of about 700 feet, and that on the east side of the great Arenig mountain there is a remarkable deposit of small rounded pebbles and sand at an elevation of not less than 1000 feet above the sea.

Causes of Driftless Areas.—With regard to the areas S. and N. of Pont Fadog, N. and N.W. of Minera, and the Moelfre-uchaf and Frithog areas, two theories might be proposed as an explanation, (1) the occupation of the areas by land-ice, which blocked out the sea, and (2) the non-exposure of the areas to tempestuous seas, or seas capable of rounding stones within the period during which the land stood at the required level. The advocates of land-ice might appeal to ice-capped islands surrounded by deep water (such as those in the Franz Josef Land group) as modern "analogues" of what may possibly have been the condition of Moelfre-uchaf and other Welsh mountains during some part of the glacial period. With regard to North-central Wales, the comparatively land-locked position of the district may have prevented it from being much exposed to tempestuous seas, or land-ice may have capped the mountains down to the level of the lower boundary of the marine drifts of the outer slopes, while the sea may have found its way up what is *now* the valley of the Dee, but *then* a fiord, so as to accumulate the gravel and sand above noticed. In connexion with this subject it may be remarked that the interior of the southern part of the Penine Hills is almost entirely free from rounded gravel and sand. Mr. John Aitken (if I understand him correctly) believes that there the sea was blocked out by snow and ice. Both areas (the north Welsh central and the southern Penine) likewise agree in being almost entirely free from erratic stones *.

VI. Boulders and Drifts on Moel Wnion.

My first search for erratic stones on this mountain (which is situated near Aber, North Wales) was unsuccessful; but during two ascents in last August and September (1881), I found five specimens of granite, including a small boulder and a pebble, a short distance below the summit, and three boulders in the cairn, on the summit, the height of which is 1905 feet above the sea-level. To make sure that the latter had not been carried up hill (a circum-

* I lately found a rounded chalk-flint on the N.W. side of Bala lake; and Professor Green, many years ago, informed me that he had found granite in the Wye valley, near Buxton; and I once saw a small granite boulder in Castleton, which had been dug up from a considerable depth in the churchyard.

stance in itself extremely unlikely) I wrote to Mr. John Parry, parish clerk of Aber, who, being a very old man, was able to assure me that the stones composing the cairn were all gathered from the flat summit of the mountain, none of them having come from a greater distance than fifty yards. Though some of the specimens somewhat resembled Mourne-mountain granite (chips of which had been kindly sent to me by Professor Hull), I believe that most if not all of them came from Scotland. I was sufficiently familiar with Eskdale granite *in situ* to be convinced that none of them came from that quarter.

Were the Boulders transported by Glaciers or Floating Ice?—A little consideration will show that the granite could not have been brought to Moel Wnion from Scotland by land-ice if Cumberland at the same time sent off glaciers W.S.W. over the Isle of Man and (according to Professor Ramsay) S.S.W. over Anglesey, unless we can believe that the Scotch glacier, on its way S. to Moel Wnion, crossed the Cumberland glaciers on their way to the Isle of Man and Anglesey, a feat which is clearly beyond the power of glaciers to perform. To the objection that the glaciers may not have flowed in the above directions at the same time, it may be answered that the south of Scotland and Cumberland are situated too near to each other to admit of the supposition that they were glaciated at different periods. That land-ice from the south of Scotland could not have brought the Moel-Wnion granite boulders is in accordance with statements made by Ramsay in the Quart. Journ. Geol. Soc. vol. xxxii. p. 118, to the effect that the land-ice from the N.W. slopes of the Snowdon group of mountains never quite reached the region now occupied by the Menai Strait, but spread along the seaward slopes of Moel Wnion, and across the mouth of the Aber valley towards Penmaenmawr. In this case the stream of land-ice from Snowdon would have protected Moel Wnion from any stream flowing from the north. It may therefore be regarded as almost, if not quite, certain that the granite boulders on the summit of Moel Wnion (1900 feet above the present sea-level) were brought by floating ice when the mountain was completely submerged; and this accords with the level at which Arenig boulders are found in the neighbourhood of the valley of the Dee, where I have seen none higher up than about 1900 feet*.

From the directions of numerous striæ along the coast of North Wales, as ascertained by Mr. Strahan, of H. M. Geological Survey, it is obvious that the mountainous part of the country was never invaded by land-ice from Scotland or Cumberland.

VII. Summary of Facts and Inferences.

In speculating on the origin of the high-level marine drifts described in this and in previous papers, the following facts and inferences ought to be duly taken into consideration:—

* It does not, however, necessarily follow that North Wales may not have been submerged to a still greater vertical extent during some part of the glacial period.

1. High-level marine drifts, in addition to directly local stones and stones from neighbouring areas, consist to a greater or less extent of far-travelled erratic stones, while in none of them are the stones entirely local.

2. The stones are generally much rounded, and that frequently over large areas.

3. All the great drift-areas contain a considerable, and some of them a large percentage of granite, especially Eskdale granite, which is at least partly owing to the extent to which the Eskdale area is covered with granite fragments and pebbles in positions favourable to removal by floating ice.

4. All the great drift areas (so far as yet known) are situated on or towards the outer slopes of mountain districts.

5. In the interior of mountain districts high-level drifts are either absent or limited to patches.

6. The drift-areas are more or less bounded above and below, as well as longitudinally, by areas in which the stones are angular or subangular.

7. None of them are situated further south than latitudes in which both land ice and floating ice may at one time have existed.

8. In all the areas there is a tendency to a knoll-shaped configuration, and in a greater or less number of instances a tendency in the knolls to occupy perched positions.

9. The gravel and sand generally contains very few large boulders; but the latter are common in and on the surface of the clay, which generally overlies, but in many instances graduates (on the same horizon) into gravel and sand.

10. The shells found in the drift are almost universally fragmentary, and that often, if not generally, in proportion to the roundness of the associated stones. They are likewise often confined to particular spots, as if elsewhere they had never been present, or had been destroyed by the stranding of floating ice, as is the case on many Arctic sea-shores at the present day.

11. The idea of shell-fragments having been pushed up hill along with portions of existing sea-beds is opposed by so many facts as to render it altogether untenable.

12. The extent to which the form of the ground has been preserved since the close of the great submergence can only be explained by supposing that either the time which has elapsed since that event, or the rate of subaërial denudation during that time, has been overestimated; in other words, the denudation must have been slow in proportion to the length of time in order to account for the little-altered surface-configuration of the drift-areas described in this and in my former paper*.

* In these areas there is an absence of the kind of gravel which a glacier would have brought along with shells from the preglacial bed of the Irish sea.

Discussion.

Prof. Hughes thought that the drifts of Derwen and Moel Uchaf were to be distinguished from those of the Minera region. The former were in the Bala lake-trough; and striations showed that there were local peculiarities in the glacial phenomena. He thought that the terraces mentioned by the author were connected with a ponding back of the Clwyd. The marine drift ran up the Elwy valley far from the sea. The Minera drifts were obviously a coast-deposit. The shells in these beds could not have existed when land-ice came down to the sea from the great mountain districts. Flints were always present, iron-stained, as if derived from flint-gravel. He thought it would be worth calculating the percentage of flints in the gravels, tracing them from this district to E. and N.E. He regarded these deposits as postglacial, and thought there was a period of great ice-extension, then of a melting-back of the local ice during submergence, and that these Minera drifts were the result of the winnowing of the Boulder-clay.

19. ANALYSES *of* FIVE ROCKS *from the* CHARNWOOD-FOREST DISTRICT. By E. E. BERRY, Esq. Communicated, with *Notes*, by Prof. T. G. BONNEY, M.A., F.R.S., Sec.G.S. (Read December 21, 1881.)

THE following analyses, undertaken by the author at the request of Prof. Bonney, may have, it is hoped, an interest not only of themselves, but also when viewed in connexion with the remarks previously made upon the rocks by Messrs. Hill and Bonney in communications already presented to the Society:—

(1) *Hornblendic Granite of Mount Sorrel.*

SiO_2		69·94
Fe_2O_3*	19·87	10·82
Al_2O_3†		9·05
MnO		trace.
CaO		3·21
MgO		1·38
K_2O		3·82
Na_2O		1·32
H_2O		1·30
Total		100·84

(2) *Syenite from Markfield.*

SiO_2		56·78
Fe_2O_3	28·30	18·81
Al_2O_3		9·49
MnO		trace.
CaO		6·94
MgO		2·71
K_2O		2·42
Na_2O		2·73
H_2O		1·10
Total		100·98

This rock may be taken as a typical example of the coarser variety of the southern syenites. The analysis confirms our remark, that they are "somewhat intermediate between typical quartz-syenites and quartz-diorites." The percentage of silica, however, is very slightly lower than we should have anticipated from our microscopic examination. (T. G. B.)

* The iron in all these rocks has been estimated as *ferric* oxide.

† This rock, as well as the Syenite from Markfield (No. 2) and the "porphyroid" of Sharpley (No. 5), contains a small quantity of phosphoric acid, which has not been estimated or separated from the alumina.

(3) *Syenite from Garendon Quarry* *.

SiO_2		51·54
Fe_2O_3	31·78	26·83
Al_2O_3		4·95
P_2O_5		0·59
MnO		trace.
CaO		9·92
MgO		4·15
K_2O		1·28
Na_2O		2·11
Total		101·37

This is a fairly typical specimen of the "northern syenites." While leaving these still classed with the syenites and maintaining their petrological relations with the southern group, we called attention to their apparently more basic character and closer relations with the diorites. This conclusion, formed after examination with the microscope, is fully confirmed by the above analysis. The amount of Al_2O_3 seems exceptionally low, as that of Fe_2O_3 is high. The author, indeed, informed me that he was not quite satisfied with the results of the method which he had adopted for separating the one from the other. (T. G. B.)

(4) *Syenite from Huncote Quarry, Croft Hill.*

SiO_2		64·30
Fe_2O_3	22·64	4·75
Al_2O_3		17·89
MnO		trace.
CaO		3·98
MgO		1·12
K_2O		3·37
Na_2O		3·84
H_2O		1·60
Total		100·85

The rock of Croft Hill is a representative of the dominant type in the outlying district in the vicinity of Narborough. It is hardly to be distinguished from that of Enderby, in the N.E., and is closely allied to that of the Sapcote *massif*, on the S.W. It differs somewhat from the rock of Barrow Hill, to the west, and that near Narborough village, to the E.N.E. We remarked upon its general relations to the finer variety of the southern syenites of Charnwood, perferring to connect it with these rather than with the Warwickshire diorites. This is borne out by the analysis, though the difference in the percentage of SiO_2 is a little greater than we should

* This rock and the "porphyroid" of Sharpley (No. 5) were dried before the analyses were made; and the amount of water present was not determined.

have expected. The Croft Hill rock thus appears to be intermediate between the "southern syenites" of the Forest and the Hornblendic granite of Mount Sorrel, on its eastern margin. (T. G. B.)

(5) *The "Porphyroid" of Sharpley.*

SiO_2		67·96
Fe_2O_3	25·47	10·60
Al_2O_3		14·87
P_2O_5		trace.
MnO		trace.
CaO		1·69
MgO		1·10
K_2O		trace.
Na_2O		5·07
Total		101·29

This rock is very fully discussed in our third communication (vol. xxxvi. pp. 342–345), in which we come to the conclusion that it is probably an altered volcanic tuff. The amount of silica is distinctly lower than in the rock which occurs in fragments in the agglomerates of this neighbourhood, which gave a percentage of about 77·7. The rather variable quantity of free quartz in both may, however, account for the discrepancy. We are surprised at the great predominance of Na_2O over K_2O; for we certainly recognized orthoclase, as well as a plagioclastic felspar among those present in the Sharpley rock.

The results of the above analyses accord (except in this last respect) as nearly as could be expected with those deduced from microscopic examination, and are therefore of interest as confirming the utility of that method of investigation. (T. G. B.)

20. *On a Proposed* Devono-Silurian *Formation.* By Professor Edward Hull, LL.D., F.R.S., F.G.S., &c., Director of the Geological Survey of Ireland. (Read January 11, 1882.)

The beds which I propose to group under the above title are found at various parts of the British Isles, and only to a slight extent, if at all, in Belgium and France *. The formation is therefore eminently British, and goes by various local names where it occurs. But it seems desirable that the relations of these detached groups to each other should be more clearly defined than has hitherto been done—and also that one definite term should be applied to designanate them, such as that I have ventured to place at the head of this paper †.

I shall commence by the admission that the coining of new names is objectionable, and is not agreeable to my own inclinations. But in this case, at least, it seems unavoidable, because, where there are several competitors for the honour of giving a name to a large and distinguished family of rocks, with apparently equal claims, the simplest solution of the difficulty of choice seems to be to select a name which belongs to none of the candidates, but which will serve to designate the social standing of them all. The term "Devono-Silurian," as it seems to me, meets the case, as it indicates that the disconnected groups of strata which I propose to include under it lie at the margin of the two great formations—the Devonian on the one hand and the Silurian on the other. They form, in fact, the connecting links between the two series, though generally found dissociated from one or other of their neighbouring formations.

I shall commence by indicating the British localities for representatives of the Devono-Silurian formation, and give at the same time a description of their characters and stratigraphical position. Fortunately, this need only be brief, as each locality has already received no small amount of attention from previous writers.

Only one Old Red Sandstone.—Let me here clear the ground for my proposal by endeavouring to dispel from the minds of British geologists the idea that there are two formations entitled to be called respectively "Upper" and "Lower" Old Red Sandstone. Until recently I was myself under this impression; and the doctrine being upheld by many high authorities, I clung to it tenaciously till I went through the process of disenchantment which was brought about by my visits to Belgium and Devonshire in 1879. The results of these visits have already been published ‡; and not the least important to myself was that by which I discovered that there is

* *Posteà*, p. 203.—It is possible that in America these beds may be represented by the lower portion of the "Gaspé Sandstones" with plants.

† This term I adopted when drawing up Tables of the Devonian and Carboniferous systems for the British Committee of the International Geological Congress, to be held at Bologna this year.

‡ Quart. Journ. Geol. Soc. May 1880, p. 255.

only one "Old Red Sandstone" properly so called, and that this lies at the top of the Devonian, and immediately below the base of the Carboniferous, series. It is in fact the upper arenaceous portion of the Upper Devonian division. All other so-called "Old Red Sandstone" formations are representatives either of the Middle and Lower Devonian beds or of those which I propose to call "Devono-Silurian" beds, lying on the confines of the two great groups each of which bears one of these names. Let it be stated once for all that the only formation entitled to the name of "Old Red Sandstone" is that which, composed essentially of arenaceous materials, and lying immediately below the base of the Carboniferous series of England and Wales, Ireland, Scotland, and the continent, is known and described as follows :—

LOCALITIES OF THE "OLD RED SANDSTONE," PROPERLY SO CALLED.

(*a*) *Continental.*—The *Psammites du Condroz* (Lower division of M. Gosselet). An important series of grey and reddish sandstones, grits, and subordinate bands of shale, of which the upper part seems to graduate into the Carboniferous beds, the lower to be connected with the Upper Devonian series. These beds are largely developed in Belgium, and are of marine origin *.

(*b*) *Devonshire.*—The *Pickwell-Down Sandstone* of North Devon, surmounted by the "Upcot Flags" (=Kiltorcan beds). An important series of sandstones and grits, grey below, red and purple above, lying below the base of the Carboniferous series (the Baggy and Marwood beds with *Cucullæa* and *Adiantites*), and above the "Morthoe slates. Mr. Champernowne has identified this sandstone in South Devon.

The view that the Pickwell-Down Sandstone is the true representative of the Old Red Sandstone of the South of Ireland has received the sanction of the President of the Geological Society in his recent elaborate address †.

(*c*) *South Wales and Hereford &c.*—Yellow Sandstone and Conglomerate of De la Beche. A thick series of yellow grits, sandstones, and conglomerate beds, lying immediately below the "Lower Limestone shale," and above the great series of red sandstones and marls with "Cornstones" (Estuarine Devonian). These beds are undoubtedly in the position of the Pickwell-Down Sandstone south of the Bristol Channel, and ought to be separated in geological maps from the underlying beds, which represent the Devonian series of the same district.

(*d*) *Ireland.*—Grey, yellow, and reddish flagstones and shales, with fishes, also with *Anodonta Jukesii* and plants (*Adiantites hibernicus*) &c. (Kiltorcan beds), passing down into red sandstone and conglomerate at base, everywhere unconformable to the beds on which they rest, as shown by Sir R. Griffith. In thickness from

* These beds have also yielded plants, and amongst others "*Palæopteris* (*Adiantites*) *hibernica*" (Mourlon, 'Géol. de la Belgique,' p. 88).

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 192. In the flagstones at the top of these beds the *Adiantites* has been found, as stated by Mr. Etheridge, who does not yet despair of finding *Anodonta*. May this hope be realized!

2000 to 3000 feet, but (owing to overlapping of the Carboniferous beds) sometimes entirely wanting in the south-west of Ireland *.

In the north of Ireland these beds are represented in the Curlew Hills and along the north shore of Clew Bay, &c.

(*e*) *Scotland.*—At the base in Haddingtonshire and Berwickshire it consists of a lower portion of brecciated conglomerate, and of an upper series of red sandstones and marls, containing *Cyclopteris* (*Palæopteris*), *Bothriolepis*, &c., passing into the base of the Calciferous Sandstone series. To these upper beds the Dura-Den sandstone with fishes belongs ; it is probably on the horizon of the Kiltorcan beds of Ireland.

All the above beds are, I believe, representative in time of each other and of the true Old Red Sandstone, and precede the lowest Carboniferous strata, which are essentially of marine origin †. The fish-remains from the beds of this group are different in the main from those of the (so-called) Lower Old Red Sandstone of Scotland ; and, according to Mr. Etheridge, no genera or species of fish pass into the Carboniferous beds ‡. Their lacustrine origin is attested by the presence of *Anodonta* both in the south of Ireland and (as Prof. Lebour has shown) at the base of the Lower Carboniferous sandstones of Northumberland. On the other hand, the lacustrine conditions of the British Isles seem to have given place to those of a pelagic character over the Continental area adjoining.

Having thus endeavoured to show what beds properly represent the Old Red Sandstone, and their true position in the geological series, I proceed to describe briefly those referable to the formation I propose to call "Devono-Silurian."

Localities of the Devono-Silurian Formation.

As already stated, the strata represented by the above title lie at the confines of the two great groups bearing these names respectively.

Though they are in some places known by the name of "Old Red Sandstone," with or without the prefix of "Lower," they are in reality separated by a wide interval of geological time from the Old Red Sandstone properly so called. This interval (as I have shown in papers already published) finds its record in the Lower, Middle, and partly in the Upper Devonian series—that is to say, in all those marine strata which in Devonshire lie between the "Pickwell-Down Sandstone" above and the "Foreland Grits and Slates" below, containing 195 genera and 544 species of marine forms, of which only 32 genera and 51 species pass into the Carboniferous group §. I mention this on the authority of Mr. Etheridge, in

* Proc. Royal Dublin Soc. vol. i. new ser. (1880), pp. 135–150.

† Quart. Journ. Geol. Soc. vol. xxxiii. p. 616 &c. I am uncertain whether these beds may not include a portion of the Lower Calciferous Sandstone of the Clyde, which is not unlike the Old Red Sandstone of the Curlew Hills &c. in Ireland.

‡ Anniversary Address. Quart. Journ. Geol. Soc. vol. xxxvii. p. 195. *Coccosteus* is the most abundant of the fishes from the Kiltorcan beds of Ireland.

§ Etheridge, Quart. Journ. Geol. Soc. vol. xxxvii. p. 197. As Mr. Etheridge has, in his Presidential Address, given his sanction to the views I have put for-

order to show what a wide interval of time separates the beds usually called "Upper" and "Lower" Old Red Sandstone. The grouping together under the same name of two sets of strata actually separated by a whole formation of such importance as the Devonian has no parallel in geological nomenclature, and can only be a source of confusion to the mind when endeavouring to grasp the order of succession of geological periods. It is time, therefore, that we should adopt some designation that will in itself exclude the idea of association.

I shall now enumerate the localities for these beds in the same order as that adopted for the beds of the Old Red Sandstone, commencing with the Continent.

Localities of the Devono-Silurian Formation.

(*a*) *Continental.*—Owing to the hiatus, or discordancy, which exists in Belgium and France at the base of the Devonian series, there are no passage-beds into the Upper Silurian, which is generally altogether absent; and the Devonian beds, with conglomerates at different geological horizons, rest on an old shelving shore of Lower Silurian or Cambrian grits and schists*. It is probable, however, that the Devono-Silurian series may be represented by the lower part of the "Système gedinnien" (in part) of Dumont, or the "Couches de Gedinne" of Gosselet.

(*b*) *Devonshire.*—This formation is represented by the Foreland grits and slates lying below the Lynton slates and limestones with Lower-Devonian fossils, which are largely distinctive. In former papers I have assumed, from considerations stated at length, that these beds represent both the Glengariff Grits and Slates of Ireland and the "passage-beds" of South Wales and Hereford—a view originally suggested by Professor Jukes, and supported in his recent Presidential Address by Mr. Etheridge †. These beds consist of hard, massive, red, purple, and grey grits, sometimes conglomeratic, and with irregular bands of slate. Their base is invisible, being covered by the waters of the Severn. They are separated from the Old Red Sandstone by several thousand feet of strata, composed of the Lynton, Hangman, Ilfracombe, and Morthoe groups. Their only fossils are Fucoids and Annelid-markings or burrows; and they are laid open in sections of the coast near Lynton and Minehead ‡. From their position below the base of the whole Devonian series, as well as on general grounds, we are warranted in assuming that these beds form the connecting link between the Devonian and Silurian series §.

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ward regarding the representative strata of Devonshire and other parts of the British Islands, it is scarcely necessary for me any further to insist on them here.

* Mourlon, 'Géol. de la Belgique,' pp. 31 & 51.

† Quart. Journ. Geol. Soc. vol. xxxvii.

‡ *Ibid.* vol. xxxvii. p. 196; also Proc. Roy. Dublin Soc. vol. i. New Series, pp. 136–38.

§ The position of these beds is very well represented on Mr. Ussher's Geological Map of Devonshire, which was exhibited at the Meeting of the British Association at York (Section C).

(*c*) *South Wales, Hereford, &c.* (*Welsh Borders*).—The beds referable to this group in the district north of the Severn and bordering the Wye, in which Murchison first established his Upper Silurian divisions, may be supposed to embrace all those lying above the Upper Ludlow Bone-bed extending into the lower beds of the so-called "Old Red Sandstone." The Downton Sandstone and rocks of the ridge of the Trichrag may be included in this series.

The formation is here thin and unimportant as compared with its representatives in Ireland and Scotland, owing probably to the shallow state of the sea-bed over which it was formed, as shown by the contents of the Upper Ludlow Bone-bed itself.

It is in this district alone that we have an uninterrupted and conformable succession, from the Upper Silurian series into the representatives of the Devonian, visibly displayed; and here we are met by another source of confusion in our geological nomenclature, because these representatives of the Devonian series are also called "Old Red Sandstone," a name which has been applied to them mainly in consequence of their prevalent red colouring, but also from the idea that they represent the "(Lower) Old Red Sandstone" of other districts. Thus it comes to pass that in the British Isles we have been accustomed to call three sets of strata, occupying three distinct geological horizons, by the favourite name of "Old Red Sandstone." Let me here name them once and for all:—

1st. The (Upper) Old Red Sandstone, representing, in fact, the Upper Devonian series in part.

2nd. "The Old Red Sandstone" of Hereford and South Wales, representing the Middle and Lower Devonian beds of Devonshire and the continent.

3rd. "The (Lower) Old Red Sandstone" of Scotland and parts of Ireland, representing the Passage-beds into the Upper Silurian series, or, as I now propose to call them, the Devono-Silurian beds.

Now, as I have shown above, it is only to the first of these that the name "Old Red Sandstone" can be properly applied. The "Old Red Sandstone" (so called) of Hereford and South Wales really represents all the beds which in Devonshire lie between the "Pickwell-Down Sandstone" and the "Foreland Grits and Slates." And here I must express my regret that I cannot concur in the views of those who regard the so-called "Old Red Sandstone" of Hereford &c. as a lake deposit. Professor Geikie considers these beds to have been deposited in one of his lakes of the Old-Red period, namely "the Welsh Lake, bounded on the north and west by the Cambrian and Silurian rising grounds, but its eastern and southern extension obscured by later formations"*. I have already expressed an opinion that these beds were deposited, not in the bed of a lake, but in that of an estuary, bounded (as Professor Geikie states) on the north and west by Cambrian and Silurian rising

* Trans. Roy. Soc. Edinburgh, vol. xxviii.

grounds, but towards the south merging into the waters of the open sea, in which were being *simultaneously* formed over the Devonshire area the fossiliferous Middle and Lower Devonian beds, with their numerous marine forms of life.

No one has ever been able to discover any traces of a barrier of older rocks which could be supposed to have separated the Devonian region from that lying to the north of the Severn and along the Wye; and I do not believe that any existed. On the other hand, the lower beds of the series contain *Lingulæ* in abundance, as, for instance, at Bedw Llewd, in Brecon—and the upper beds *Serpulæ*, as in Caldy Island. The red colour of the strata may be due to deposition either within the bounds of an estuary or in those of a lake; and in Belgium, as Professor Dewalque has pointed out*, red marls and sandstones occur, separating large masses of marine limestones of the Devonian period †.

The difference in character of the beds in Devonshire on the one hand, and in South Wales &c. on the other, need offer no impediment to the acceptance of my view, because the original horizontal distance was very much greater than at present. In order to find this out, we must restore all the highly inclined strata of South Wales and the rocks under the Severn, with their numerous flexures to the *horizontal position*; and by this means the horizontal distance will be increased by perhaps one third. This would allow space for the gradual changes of character observable between the beds of North Devon and their representatives in South Wales, Hereford, &c.

On all these grounds I venture to recommend the adoption of the term "Estuarine Devonian" for the series lying above the Passage-beds in the country bordering the Wye, the Mon, and the Usk.

(*d*) *Ireland, South.*—"Dingle beds and Glengariff Grits and Slates" (Jukes). A series of grey, green, and purple grits and conglomerates, with intervening red, grey, and green slates of great thickness (estimated at from 10,000 to 12,000 feet), passing downwards into the Upper Silurian beds in the Dingle promontory, and unconformably overlain either by the Old Red Sandstone or (in the absence of that formation, owing to conformable overlap) by the Lower Carboniferous beds ‡. The only fossils they have yielded are stems of plants and fucoidal markings. The plants are allied to Carboniferous forms (vascular Cryptogams).

These beds are placed by Murchison in the "Lower Devonian series," a very close approximation to what I conceive to be their true position; but if (as I suppose) they represent the Foreland Grits and Slates of North Devon and the "Passage-beds" of South Wales &c., they occupy a position just *below* the fossiliferous Lower Devonian beds of which the "Lynton Slates and Limestones" are the representatives. After an examination of the fine sections at the extre-

* Brit. Assoc. Rep. 1877, Trans. Sect. p. 69.

† Namely, the Calcaire de Givet from the Calcaire de Frasne.

‡ The evidence for this statement I have given in former papers—Quart. Journ. Geol. Soc. vol. xxxv. (1879), and Proc. Roy. Dub. Soc. vol. i. new series (1880).

mity of the Dingle promontory in 1878, and seeing the perfect continuity between the Dingle beds and the underlying Upper Silurian strata, I came to the conclusion that they themselves were an upper portion of the Silurian series*, representing the Upper Ludlow rocks—a view previously advanced by Sir R. Griffith. Taking into consideration, however, the prodigious development of these beds, and the consequent lapse of time during which they must have been in course of accumulation, their geographical importance, and their connexion on the one hand with the Devonian (by inference), and on the other with the Silurian system (by observation), I now prefer to place them in the position of a separate group, under the style and title of "Devono-Silurian"†.

Ireland, North ("Fintona beds").—This group is also represented in the north of Ireland by a great series of reddish grits, conglomerates, and shales, lying between the valleys of Loughs Erne and Neagh, and forming large portions of Monaghan and Tyrone. Their base reposes either on the metamorphic rocks of the north of Ireland or (unconformably) on the Lower Silurian beds of Pomeroy, charged with fossils of "Caradoc (Bala)" genera and species, as originally shown by Portlock. In this case the Upper Silurian beds are absent, and we have a hiatus at the base of the series, which is filled up in the Dingle promontory; nevertheless there is a general consensus amongst Irish geologists that the "Fintona beds," as they are now frequently designated, are the representatives in time of the Dingle and Glengariff beds; and as such they would come under the designation of "Devono-Silurian."

The position of these beds serves to connect them geographically with their Scottish representatives, which I next proceed to refer to; but they have not hitherto (like the latter) yielded ichthyic remains, or, indeed, fossils of any kind. They were probably deposited within the margin of a lake-basin, bounded in nearly all directions by unsubmerged lands formed of Lower Silurian rocks towards the south, and of their metamorphosed representatives towards the north. Eastwards this basin may have been connected by a narrow channel with Professor Geikie's "Lake Caledonia or Mid-Scottish Basin," through the Firth of Clyde, as he himself has suggested‡.

(*e*) *Scotland.*—It can scarcely be a question that the beds known in Scotland as "Lower Old Red Sandstone" are referable to the group I am now describing. Professor Geikie has already suggested that they are represented in Ireland by the Glengariff or Dingle beds, a view in which I concur; and that there is no *palæontological* difficulty in the way of the acceptance of this view may be inferred

* "On the Geological Age of the Rocks forming the Southern Highlands of Ireland," Quart. Journ. Geol. Soc. vol. xxxv. p. 699 *et seqq.* (1879).

† We have as yet no evidence from fossils regarding the conditions of formation of these beds. Careful examination by the officers of the Geological Survey has hitherto failed to bring to light any thing but plants, Fucoids, and Annelid-tracks. I incline to the opinion that they were of marine origin.

‡ "On the Old Red Sandstone of Western Europe."—Trans. Roy. Soc. Edinb. (1878).

from the statement on the subject by Mr. Etheridge in his recent Presidential Address *.

I confess to a feeling bordering on remorse in throwing a doubt on the propriety of the name which has been associated with these beds by the Scottish geologists, including the honoured names of Boué, Macculloch, Hugh Miller, and those of more recent times; and I almost despair of persuading my Scottish contemporaries that the only true Old Red Sandstone to which their country can lay claim is the *comparatively* insignificant series of sandstones and conglomerates which (in geological sequence) unconformably overlies the great ichthyic formation of "Lake Orcadie," or "Lake Caledonia," and of "Lake Cheviot," and underlies the Calciferous Sandstone of the Lower Carboniferous series.

It is scarcely necessary for me to do more than allude to the great Scottish formation, so well described on a recent occasion by Professor Geikie as occupying several distinct old lake-basins, surrounded by Silurian or Metamorphic rocks, and attaining in Caithness an estimated thickness of 16,200 feet, with its magnificent assemblage of fossil fish, amounting to about 18 genera and 60 species, together with Crustaceans and plants. This ichthyic fauna redeems the great Devono-Silurian group from the charge of well-nigh utter barrenness. Of the character of the Molluscan fauna we have no evidence; but if (as may be supposed) the Devonian fauna was the lineal descendant of the Upper Silurian, to which, however (as Mr. Etheridge has shown), it bears very little specific resemblance, then the fauna of the Devono-Silurian period must have had a *facies* of an intermediate character between the Upper Silurian on the one hand and the Devonian on the other. This fauna must have occupied some pelagic region outside the limits of the British Isles and of Western Europe.

Summary.—To briefly recapitulate, I include, therefore, under the name "Devono-Silurian" the following:—

(1) The grits, conglomerates, and slates lying at the base of the Lower Devonian series of Belgium, &c. ("système Gedinnien").
(2) The Foreland Grits and Slates of Devonshire.
(3) The "Passage-beds" of South Wales, Hereford, &c., including the Downton Sandstone and the beds of the ridge of the Trichrag.
(4) The Dingle and Glengariff Grits and Slates of the south of Ireland.
(5) The Fintona-beds of the north of Ireland.
(6) The so-called "Lower Old Red Sandstone" of Scotland, belonging to several basins.

* The President of the Geological Society states as follows:—"If Professor Geikie is right in saying that the Scotch Old Red Sandstone represents the Irish Glengariff beds, then Professor Hull may be right in concluding that the Scotch beds are the lacustrine equivalents in time of the marine uppermost Silurian strata."—*Op. cit.* p. 197.

South-east of England.—There is probably only one district in the British Isles where the *marine* representatives of the entire series, from the Upper Silurian to the Carboniferous, exist in unbroken sequence—namely, the tract covered by the Cretaceous and Tertiary beds north of London. *There,* I anticipate, we should find, were the newer strata stripped off, a continuous succession from the Wenlock, through the Ludlow, the Devono-Silurian, Devonian, and Old Red Sandstone, to the Lower Carboniferous beds, between Ware, in Hertfordshire, and the North Downs of Kent and Surrey. As Mr. Etheridge has shown *, the Wenlock beds have been proved in a boring at Ware, under the Gault; and he conjectures that the Ludlow beds might be found "under, or a little to the south of Hertford," while the Devonian beds have been proved to exist at Turnford and Tottenham Court Road. Between these places and Hertford we may therefore infer that the Devono-Silurian beds lie concealed beneath the Chalk. The series here has its parallel in South Wales and the border districts, except that *there* the Devonian series occurs as an abnormal estuarine, instead of as a marine, deposit.

The following Table gives the succession of the geological series downwards, which, from its simplicity, will, I trust, commend itself to the reader, while it brings the series into direct harmony with those of the Continent and America.

Table of Succession of Formations in the British Isles.

Lower Carboniferous Beds.	1. Carboniferous Limestone. 2. Lower Carboniferous Shale or Slate (England and Ireland). 3. Coomhola Grits and Slates (Ireland); Pilton, Baggy, and Marwood beds (Devonshire).	
Old Red Sandstone (Upper Devonian, in part).	1. Kiltorcan beds, with *Palæopteris* and *Anodonta,* fish (*Bothriolepis, Coccosteus, Glyptolepis,* and *Asterolepis?*) and Crustaceans (Ireland). 2. Old Red Sandstone and Conglomerate (Ireland), Pickwell-Down Sandstone (Devon), Yellow Sandstone and Conglomerate (Monmouth, Brecon, &c.).	
Devonian beds.	1. Morthoe slates (Devon). 2. Ilfracombe and Plymouth limestone group. 3. Hangman Grits and Slates (Devon). 4. Lynton Shales and Limestones (Devon).	Estuarine Devonian beds of Hereford (so-called Old Red Sandstone).
Devono-Silurian beds.	Foreland Grits and Slates (Devon); Downton Sandstone and Passage-beds (Hereford, &c.); Glengariff Grits and Slates (or Dingle-beds) (Ireland); and Lower Old Red Sandstone (Scotland); Système Gedinnien in part (Belgium).	
Upper Silurian beds.	Upper, Lower } Ludlow beds. Wenlock beds, &c.	

* Anniversary Address, p. 230 (*supra cit.*). In the 4th edit. of the 'Coal-fields of Great Britain' (1881), I have given an engraved section to show the probable succession of the Palæozoic beds of this part of England beneath the overlying Mesozoic and Cainozoic strata.

Discussion.

The President said that the paper was a very suggestive one, which raised a number of very doubtful questions.

Prof. Hughes pointed out that he had already (Brit. Assoc. 1875) suggested a twofold classification of these deposits, but he did not refer the same beds as did the author of the paper to the upper and lower divisions. The beds which followed the Silurian without a break, and which he called Sawdde beds, from the river in Caermarthenshire along which the best continuous section is seen, were, he thought, older than the oldest Devonian, and the base of the Devonian was represented by the quartz-conglomerates which rest upon the Sawdde beds and underlie the brown sandstones of the Vans. This upper division he considered the variable basement-series of the Carboniferous, and thought that it was the equivalent of the thin conglomerates &c. known as the Old Red in North Wales and in the north of England, and of the Middle and Upper Old Red of Scotland and the north of Ireland.

Mr. Champernowne agreed with the views of Prof. Hull as to the estuarine rather than lacustrine character of the Welsh Old Red, regarding it as probable that the two areas, Welsh and North Devonian, were united at the period of the (Upper) Old Red Sandstone, though they might have been separated during the accumulation of the Cornstone series and the Middle and Lower Devonian beds. Consequently he thought it impossible that the Foreland beds could represent the quartz-conglomerate at the base of the Brownstone group, which he had understood Prof. Hughes to suggest, but that they were much older. Still he did not like the name "Devono-Silurian" for the Foreland beds and their presumed equivalents. He thought that a more detailed examination of them had been made by Mr. Ussher than perhaps by any other observer; and he hoped that he might see his North-Devon lines adopted by the Survey.

Rev. H. H. Winwood referred to the difficulty of working the Foreland beds on account of their inaccessibility.

The President said one of the chief points of Mr. Hull's paper was that the Pickwell-Down Sandstones are the equivalents of the Herefordshire and Welsh and all the Old Red Sandstone, and that his views had been quite misunderstood in the discussion.

21. *On the* TWO BRITISH TYPES *of the* LOWER CAMBRIAN BEDS, *and the* CONDITIONS *under which they were respectively deposited.* By Prof. EDWARD HULL, LL.D., F.R.S., F.G.S. (Read January 11, 1882.)

THE subject of this paper forced itself on my mind when drawing up an essay "On the Laurentian beds of Ireland;" and I had originally intended to place it as an appendix to that communication*; but on further consideration I have thought it of sufficient interest to deserve separate treatment.

I propose to compare the Cambrian beds of the North-west Highlands of Scotland, which I shall call those of the "Caledonian type," with their supposed representatives in South Britain and Ireland, which I shall call those of the "Hiberno-Cambrian type," as regards both their petrological characters and their fossil contents, with the view of showing that they were formed respectively on either side of a ridge (or barrier) of Archæan rocks, which a recent examination of the north of Ireland enables me to trace along its whole course in the British Isles.

Before entering, however, on this special subject, I ought first to state the geological position of the beds I here call "Cambrian," as the term is unfortunately rather widely applied at present amongst British geologists.

Definition of "Cambrian" Beds.—For my present purpose I use the term within the limits in which it is used by the Geological Survey—that is, the "Lower Cambrian" of Sedgwick, including the beds below the Lingula-flags and the Menevian stage of Salter and Hicks. To this stage, therefore, the Llanberris, the Harlech, and Longmynd rocks are presumably referable.

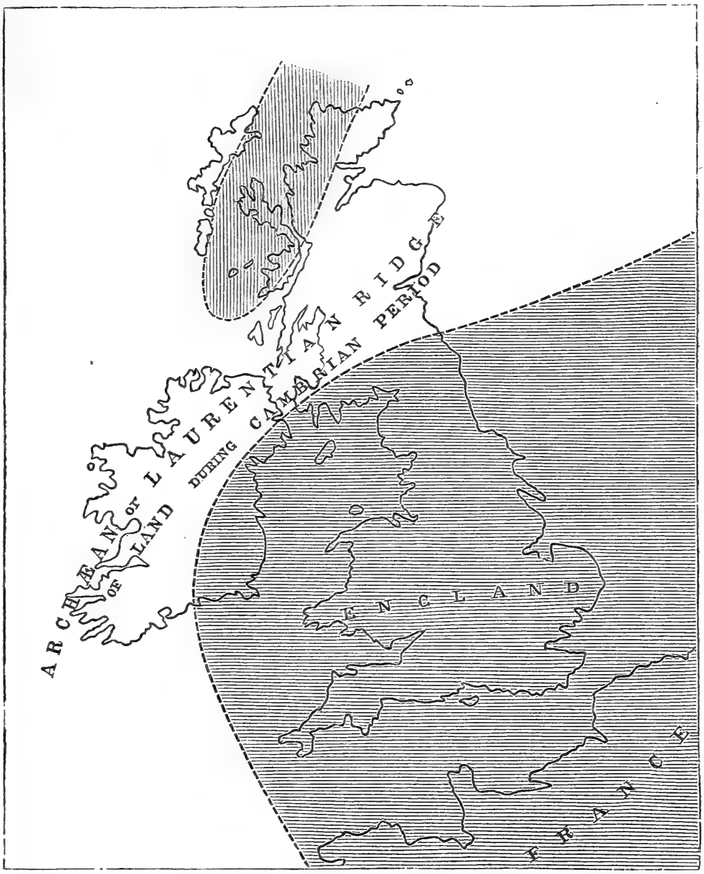
I assume, then, the above great group of conglomerates, grits, and slates to be the representatives in time of the Cambrian beds of the North-west Highlands of Scotland, and for the following reasons:—

In the Highlands the Cambrian beds are overlain transgressively by quartzites and limestones, the latter containing fossils chiefly of American Lower-Silurian types, as Salter has shown, but, so far as the evidence goes, referable to the stage of the Llandeilo beds† of Wales. There is therefore in the Highlands a hiatus between the Lower Silurian beds and the Cambrian sandstone, which we may well suppose is represented elsewhere by the "Menevian," "Lingula," "Tremadoc," and possibly "Arenig" beds. It is, of course, impossible to say whether all, or how many, of these stages are wanting; but certainly some of them are absent, owing to the unconformity observable in the North-west Highlands—an unconformity which is itself partially represented even in Wales, where all these stages occur.

* Scient. Trans. Roy. Dublin Soc. vol. i. ser. 2, p. 240.

† Quart. Journ. Geol. Soc. vol. xv. p. 374, with plates; also 'Siluria,' 4th edit. pp. 164–5.

Fig. 1.—*Map showing approximate Boundaries of the two British Cambrian Basins and of the intervening Archæan Ridge.*



Caledonian Basin.

Hiberno-Cambrian Basin.

The representative sections in the two areas may therefore be approximately coordinated as follows:—

	N.W. Highlands of Scotland.	*Welsh District.*
LOWER SILURIAN (Llandeilo Beds?)	Quartzites. Limestones with fossils. Fucoid beds. Quartzites with Annelids.	Lower Silurian (Llandeilo) beds.
Not represented ...	Hiatus	Arenig beds? Tremadoc beds. Lingula flags. Menevian beds.
CAMBRIAN.	Red sandstone and Conglomerate.	Cambrian beds. (Harlech, Llanberris, Longmynd, and St.-David's beds).

As regards the base of the Cambrian beds, *that* is well defined in the Highlands; and if it should ultimately appear that the base of the representative beds has been really discovered in Anglesey, as stated by Prof. Hughes, Dr. Hicks, and Dr. Callaway* (a point on which I have no opinion to offer), then the lower, as well as the upper, limit of the formation here described will have been well determined in each country.

Now let us compare these presumed representative beds as they occur in the Highlands of Scotland, in Wales, and in Ireland.

a. *Cambrian Beds of the Caledonian type. N.W. Highlands of Scotland.*

Sir R. Murchison's description is sufficiently full for my purpose, and is as follows:—

"The ancient gneiss, along the coast of Sutherlandshire and Ross, is surmounted by great masses of dull brown, red, and chocolate-coloured sandstone and conglomerate" †, generally in nearly horizontal courses, rising into the mountains of Coulmore, Suilven, Canisp, and Queenaig. The reddish tint is everywhere prevalent; and there is a remarkable absence of beds of slate ‡; the deposits are likewise unfossiliferous.

The beds, it will be observed, are not described as "grits," a term only applicable to those I am about to describe.

There are no traces of such beds in the north or west of Ireland, between the representatives of the Lower Silurian series and those of the Laurentian; I therefore include the north, the west, and the centre of Ireland in the Archæan ridge, which was prolonged from the central Highlands of Scotland (see Map, fig. 1).

b. *Cambrian Beds of the Hiberno-Cambrian Type.*

For the description of these beds as they occur in the Welsh and Salopian area, I adopt the language of Prof. Sir A. Ramsay. "The Cambrian rocks of Wales," he says, "consist of the purple grits and slates that form the greater part of the group of hills lying east of Cardigan Bay." . . . . . "They are also well seen in the passes of Llanberris and Nant Ffrancon, where the celebrated slate-quarries of Penrhyn and Llanberris lie in these strata. The slates are purple, purplish-blue, and green; and associated with them are beds of greenish and grey grits and conglomerates" §. Again, the Longmynd rocks "consist of green, grey, and purple slaty rocks, grits, and conglomerates," in which are worm-burrowings, and a Trilobite (*Palæopyge Ramsayi*) discovered by the late Mr. Salter.

* "Archæan Geology of Anglesey," Quart. Journ. Geol. Soc. May 1881.

† Quart. Journ. Geol. Soc. vol. xv. p. 362.

‡ Sir R. Murchison compares these beds to their representatives in the Longmynd hills of Shropshire; but there is a marked general absence of resemblance between the "grey and purplish slaty, gritty, and pebbly rocks" of the Longmynd (Phillips) and the reddish sandstones and conglomerates of Ross-shire.

§ Phys. Geol. Great Britain, 5th edit. p. 58.

The Cambrian beds of St. David's are similar in composition to the above, and have yielded to Dr. Hicks a peculiar marine fauna, consisting of Trilobites, Brachiopods, &c., the most ancient group of these forms known in Britain.

The beds of the same horizon in the east of Ireland are not dissimilar, allowance being made for geographical space. They are of great but unknown thickness, consisting of green and purple grits, quartzites, and rough slates. Conglomerate beds are rare. The fossils yielded consist only of tracks and burrows of marine worms and two species of a peculiar form of zoophyte called, after its discoverer, *Oldhamia*. These beds are unconformably overlain by the Lower Silurian slates and grits, the hiatus here recognizable being due to the absence of the Menevian, Lingula, and Tremadoc stages.

All the palæontological evidence at present existing goes to show that the Cambrian beds of the Hiberno-Cambrian type of England, Wales, and Ireland were deposited in one connected basin, and in the waters of the ocean; and in this as well as in their petrological characters they offer a strong contrast to the beds of the Caledonian type, which I concur with Professor Ramsay in considering to have been deposited in a lake-basin*.

These differences are so great that they seem of themselves to point to deposition within the limits of distinct basins; and this view receives further confirmation from the second kind of evidence, that depending on certain geometrical considerations I am now about to adduce.

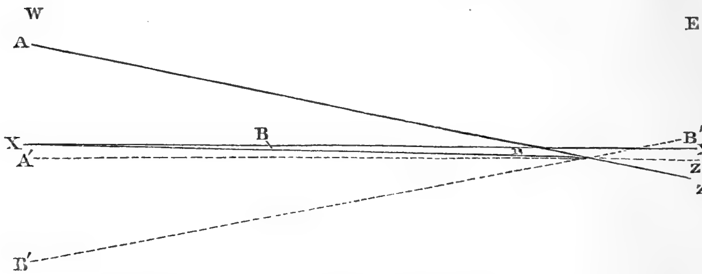
It is known that all along the western outcrop of the Lower Silurian quartzites and limestones, from Loch Erriboll in the north to Loch Carron in the south, the dip is easterly, and these beds pass transgressively across the truncated edges of the horizontal beds of Cambrian sandstone†. These sandstones rest upon an eroded surface of Laurentian beds, with a (generally) very slight inclination eastward. Between the slope of the Silurian beds and that of the Laurentian floor there is generally a considerable angle, so that the two planes ultimately collide—as, for instance, at Loch Maree in the south, and Loch Assynt in the north ‡. If, therefore, we reduce the plane of the Lower-Silurian beds to its original nearly horizontal position, the other plane, formed by the Laurentian floor, becomes tilted upwards towards the east; in other words, it rises in the direction of the central Highlands. This is illustrated by the following diagram (fig. 2):—

* Quart. Journ. Geol. Soc. vol. xxviii. Dr. Mourlon refers the rocks of the Ardennes in which *Oldhamia radiata* occurs to the "Cambrian system" (Géol. de la Belgique, t. i. p. 31, 1880).

† Murchison and Geikie, Quart. Journ. Geol, Soc. vol. xvii. pp. 184, 190. I have endeavoured to illustrate this point by a diagram in my paper on the Northern Highlands of Scotland in Scient. Proc. Roy. Dubl. Soc. vol. iii. pl. x. fig. 5.

‡ Murchison and Geikie, *suprà cit.* p. 191.

Fig. 2.—*Diagram showing Present and Original Positions of Strata.*



X X. Approximate sea-level or horizontal line.
A Z. Present base of the Lower Silurian beds.
A′ Z′. Original position of ditto.
B B. Present basement floor of the Cambrian sandstone.
B′ B′. Original position of ditto.

It will thus be seen that the floor of the Cambrian sandstones, formed of Laurentian rocks, must have originally sloped upwards towards the central Highlands, and in that direction probably formed a ridge during a portion, or the whole of the period in which the Cambrian beds were being deposited. This ridge would form the eastern margin while that of the outer Hebrides would, as suggested by Professor Ramsay, form the western margin, of the basin in which the Cambrian beds of the Scottish type were deposited.

On the other side of this ridge, which embraced the Scottish Highlands and the north and west of Ireland, the Cambrian beds of the Welsh and Irish type were deposited in a much larger basin*, into which the ocean waters gained access at intervals, if indeed, as seems to me more probable, they did not prevail throughout the entire period†.

What may have been the eastern and southern limit to the Cambrian beds of the Hiberno-Cambrian type it is less easy to indicate. The floor of these beds crops up in Bohemia, and probably in Central France and Brittany; but it would be hazardous to assert that the old crystalline rocks of these regions were never covered by the Cambrian beds of the Ardennes.

Thus it is that we are in possession of two kinds of evidence, perfectly distinct, but both pointing to the conclusion with which I commenced, viz. that of the existence of two distinct basins in the Cambrian period, one lacustrine and the other marine, lying on either side of a ridge of Archæan metamorphic rocks.

* Prof. Ramsay, judging by their mineral characters, considers that the Cambrian beds of Wales were deposited in proximity to land (Phys. Geol. Great Brit. 5th edit. p. 67).

† I include in the second (Hiberno-Cambrian) type of Cambrian beds the rocks of Charnwood Forest, which were originally referred by Jukes to this formation; and I have not seen sufficient evidence, notwithstanding all that has been since written, that he was in error.

Discussion.

Dr. Hicks congratulated Prof. Hull on the change which this and other recent papers of his showed in his views with regard to the pre-Cambrian rocks. It was quite clear that the acknowledgment of a pre-Cambrian ridge in the central part of Scotland up to a late period in the Silurian was a step towards the view of Dr. Hicks, that this ridge, which was at the close of the Cambrian the highest point, and the last submerged and overlapped by sediments, has become reexposed during the elevation and denudation of the more deeply buried adjoining portion of the old floor on the west coast. He was pleased also to find that Prof. Hull now accepted the pre-Cambrian age of some rocks in Wales and Ireland. Dr. Hicks did not, however, believe that the Torridon Sandstone was a lacustrine deposit, more than other sandstones and conglomerates; but he believed that the differences in the materials and in the thicknesses of these early deposits was due to their being thrown down over a gradually subsiding area, and that the old floor was in a very uneven condition at the time. He agreed with the main line of depression indicated; and it was the one he had himself pointed out in a paper read to the Society in 1875.

Prof. Judd said that Prof. Hull had certainly not committed himself to the view that the whole of the existing surface of Central Scotland was to be regarded as belonging to the Archæan.

Prof. Hughes pointed out that there was some confusion between overlap and unconformity. He thought that there was no break between the Cambrian of the Survey and the Silurian, nor at the base of the Llandeilo beds. As submergence went on, the newer overlapped the older and lay directly on that portion of the Archæan rocks which happened to be the shore. He did not think the exact position of the *Oldhamia* beds was established.

Prof. Bonney said that Prof. Hull, in still claiming the Charnwood-Forest rocks as Cambrian, appeared to be inconsistent with himself, since a main argument of his paper, for the identification of beds, was lithological similarity. Further, Prof. Hull had assumed that the Torridon Sandstone was Cambrian. Prof. Bonney, however, thought the age of that deposit was so uncertain that this was an unsafe foundation for the superstructure of an argument.

Mr. Hudleston agreed with Prof. Bonney, and thought that Prof. Hull was driven to his hypothesis in order to account for the differences in the two basins. He thought, also, that Dr. Hicks had hardly understood Prof. Hull's map.

Mr. Drew also thought that the map was not intended to refer to any thing post-Cambrian.

Mr. Champernowne said certainly Prof. Hull at York spoke of the Archæan ridge as being a concealed barrier, and did not suppose it to consist of the flaggy gneisses of the Central Highlands.

22. *Additional Note on Certain* Inclusions *in* Granites. By J. Arthur Phillips, Esq., F.R.S., F.G.S. (Read March 8, 1882.)

In a paper which I had the honour of reading before this Society on November 19th, 1879, entitled "On Concretionary Patches and Fragments of other Rocks contained in Granite," I called attention to the fact that a certain class of such inclusions, usually more or less ovoid in form and resembling imbedded pebbles, are essentially composed of a fine-grained variety of the granite in which they are severally enclosed. The proportion of dark-coloured mica in these patches is almost invariably greater than in the rock in which they occur, and imparts to them a darker colour than that of the general mass. It was further observed, when sections made through both pebble-like inclusions and the enclosing granite are examined under the microscope, that along their line of contact minute crystals are found to extend from the one into the other. These rounded inclusions sometimes enclose a second similar nodule, differing from the first either in colour or in fineness of grain only.

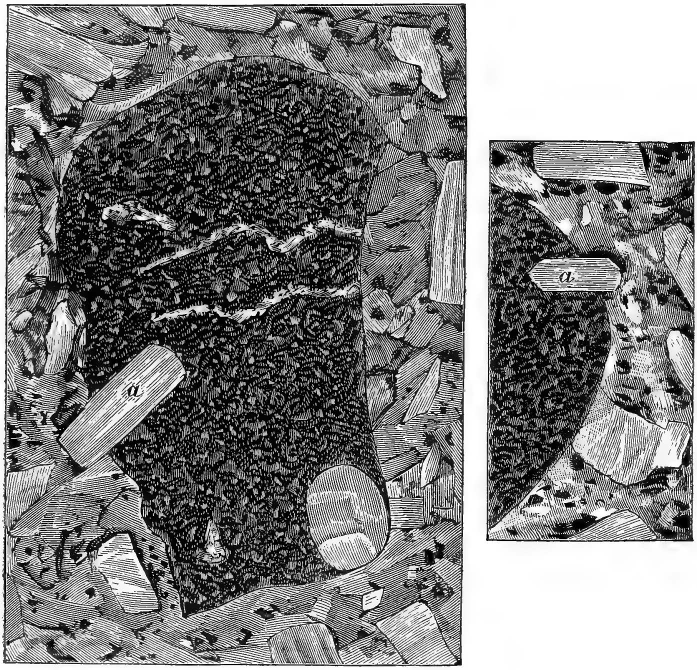
Such inclusions are sometimes porphyritic in structure, and enclose large crystals of the felspar characterizing the enclosing rock. Thus, when the felspar of the surrounding granite is either red or pink in colour, that which is porphyritically distributed through the inclusions will be correspondingly red or pink; if, on the contrary, white felspar be a characteristic of the normal granite, the porphyritic crystals of the inclusions will likewise be white. The angles of felspar crystals so enclosed in ovoid inclusions are often much rounded.

Arguing from these facts, I had concluded that rounded "inclusions" are usually contemporaneous with the consolidation of the general rock-mass, and that they are due to the action of forces of somewhat the same nature as those which have resulted in the production of the concretionary nodules of the orbicular diorite of Corsica.

Up to the time of the publication of the paper referred to, although constantly sought for, no instance had been met with of the penetration of large crystals of felspar from the surrounding granite into one of these pebble-like inclusions. More recently, however, numerous examples have been observed of a crystal of felspar from the granite penetrating an inclusion, or one of the porphyritic felspar crystals of an inclusion extending into the granite.

The accompanying woodcuts, after drawings by Mr. Frank Rutley, represent, one half natural size, a dark inclusion and a portion of a nearly similar one, penetrated by large crystals of red microcline, in Shap granite forming part of the façade of a building in Nicholas

Lane, City. These appear to afford direct evidence that the formation of the inclusions and the solidification of the enclosing granite were contemporaneous.



Inclusions in Shap granite: *a*, crystals of felspar.

DISCUSSION.

Prof. BONNEY expressed his sense of the value of Mr. Phillips's communication, which seemed to illustrate the order of solidification of the constituents. He said that in the case of the Shapfell granite the felspar crystals appeared to have been developed *in situ*.

Mr. ETHERIDGE remarked upon some small felspathic veins which traversed the inclusion, and asked if they were contemporaneous.

Rev. E. HILL asked what the signification might be of the rounding of the felspar crystals described by the author.

Mr. PHILLIPS said it was difficult to account for the rounded form of crystals in certain rocks; they often looked as if they had crystallized under restraint. In the present case, whatever had caused the segregation of the mica seemed to have interfered with the perfect formation of the felspar crystals—which, after all, was not a very satisfactory explanation.

23. *On a* FOSSIL SPECIES *of* CAMPTOCERAS, *a Freshwater* MOLLUSK *from the* EOCENE *of* SHEERNESS-ON-SEA. By Lieut.-Colonel H. H. GODWIN-AUSTEN, F.R.S., F.G.S. (Read March 22, 1882.)

[PLATE V.]

I HAVE now had by me for a long time, waiting for description, some very interesting fossils, obtained by Mr. W. H. Shrubsole near Sheerness; and I owe Mr. Shrubsole some apology for retaining them so long unnoticed. In July 1880, when looking over some of Mr. Shrubsole's fossils from the above neighbourhood, he showed me this specimen, which, he informed me, had very much puzzled several naturalists to whom he had submitted it. It recalled at once an East-Indian form with which I was familiar; but I could not at the moment give Mr. Shrubsole the name. On returning to town on the 2nd of August I looked up the genus in my collection, and wrote (confirming my original opinion) that I considered the shells to belong to Benson's genus *Camptoceras*. Dr. H. Woodward saw the same specimen in September 1880, and expressed the same opinion in a letter of the 23rd to Mr. Shrubsole; and on hearing I had previously seen the specimen and identified the genus, he forwarded the same to me in February 1881. I may also mention that Messrs. Etheridge and Newton in October, having seen Mr. Woodward's letter and reexamined the specimen, were also of the same opinion.

As it is the first record of the genus occurring fossil, I shall enter somewhat fully into an account of it, giving Benson's original description, and noticing the species now known to us.

Genus CAMPTOCERAS, Benson.

Camptoceras, Benson, Calcutta Journ. of Nat. Hist. p. 465 (1843); Ann. & Mag. Nat. Hist. (2) vol. xv. p. 9 (1855).

"Testa sinistrorsa, imperforata, elongato-elliptica, spira soluta, apice acutiusculo, sutura late et profunde excavata (re vera omnino carente); anfractibus 3–4 angustis elongatis, superne et subtus carinatis, lateribus planulatis; apicali elongato-acuminato, longe exserto; ultimo antice superne descendente, carinato; apertura soluta, integra, magna, spiram non æquante, elongato-elliptica, angustiuscula, superne et ad basin arcuatim angulata; peristomate acuto; operculo nullo."

The first species, *C. terebra* * (Plate V. fig. 8), on which it was founded, was taken by Dr. Bacon, in company with Mr. Benson, in a piece of water that had previously formed a portion of the Ram

* Ann. & Mag. Nat. Hist. (2) vol. xv. p. 10 (1855), with outline figure; Journ. Asiat. Soc. Bengal, vol. xl. 1871, pl. ii. figs. 1, 1*a*; Conch. Indica, p. 64, pl. clviii. figs. 1, 2; Adams, Gen. Recent Mol. p. 258, pl. lxxxiv. fig. 1.

Gunga river, near Moradabad in Rohilkhund, India. Benson thus describes the animal:—

"Animal tentaculis duobus filiformibus, obtusis, oculis magnis inter tentacula sitis, proboscideque mediocri munitum; pallio labia testæ haud transeunte; pede brevi, longitudinem aperturæ vix superante."

"The form of the tentacula and the position of the eyes, situated between the filiform tentacula, and sessile on the head (not as in *Lymnœa*, occupying the fore part of the widened base of the triangular tentacula), at once distinguish the animal from that of *Lymnœa*. In *Camptoceras* the eyes are large in proportion to the size of the animal, while in *Lymnœa* they present only a minute black point, even in individuals of large size." . . . . "The shortness of the foot, however, the sluggish movements of the mollusk, and its strong adhesion to smooth surfaces, point to an affinity with *Ancylus*, which, instead of presenting the elongate, imperfectly rolled, acutely spiral cone of *Camptoceras*, sinks into a widely-spread, depressed cone, with scarcely any distortion of the spire." *Ancylus* is also sinistral.

"The animal adheres, in deep water, to the decaying stems of a reedy sedge, more frequently burrowing into them, and concealing itself between the internal layers; a habit which renders it difficult to detect."

It occurred with species of *Planorbis* and *Ancylus*, was very local, and was taken in February 1842; but at the end of 1845 no more could be found, and it has never since been found by any collector in India. As Benson remarks, it may be more abundant during the rainy season in July and August; but the character of the surrounding country is not then favourable in point of healthiness or practicability for exploration.

In March 1869, when encamped near some marshes at Nazirpur, near Shushong-Durgapur, in the Mymensing district under the Garo hills, and where I often searched for shells, I was so fortunate as to discover two other species of *Camptoceras* living together. The water of the "Beels," as marshes are called there, was then fast drying up; and all the specimens that I found were adhering tightly to the surface of the dried-up water-plants, a few feet from the water's edge*. I had no leisure to watch and examine the animals, and on my arrival in Calcutta, a short time afterwards, gave them over to Mr. H. F. Blanford, who described and figured them in the 'Journal of the Asiatic Society of Bengal,' pt. ii. 1871, pp. 39–41, under the names of *C. Austeni* and *C. lineatum*, the former, of which I give an outline figure (Plate V. fig. 9), being nearest to *C. terebra*.

The fossil species is nearest to *C. terebra*, Benson, in the form of the whorls, but differs considerably in their greater number and more elongate form. Unfortunately the aperture has not been preserved entire in any of the specimens on the little block I have before me. *C. lineatum* was abundant where I found it; and the fossil species

* This same ground, a few months after, during the rains, would be 10 or 15 feet under water.

appears to have been the same, judging from the large number of specimens. Although apparently so rare a shell in India, I believe it will be yet found more widely distributed, and that other forms will be found when the enormous area of the deltas of the Ganges, Brahmaputra, and Indus is more closely searched. These shells are very minute, and can only be obtained at a certain low state of the rivers and marshes.

Description of fossil Species.

CAMPTOCERAS PRISCUM, n. sp. Plate V. figs. 1–5.

Locality. Higher level of cliffs, about halfway between East-End Lane and Hensbrook, Island of Sheppey, Kent.

Shell sinistral, very elongate; a slight indication of spiral ribbing in the casts; spire elongate; apex very acuminate and slightly curved; suture wide and deep; whorls 4, disunited, rather rapidly increasing, and constricted at intervals, then becoming tumid; aperture not well made out, evidently oblique, circular or oblate, and reflected slightly at the peristome.

Var. OBTUSUM. Plate V. figs. 6, 7.

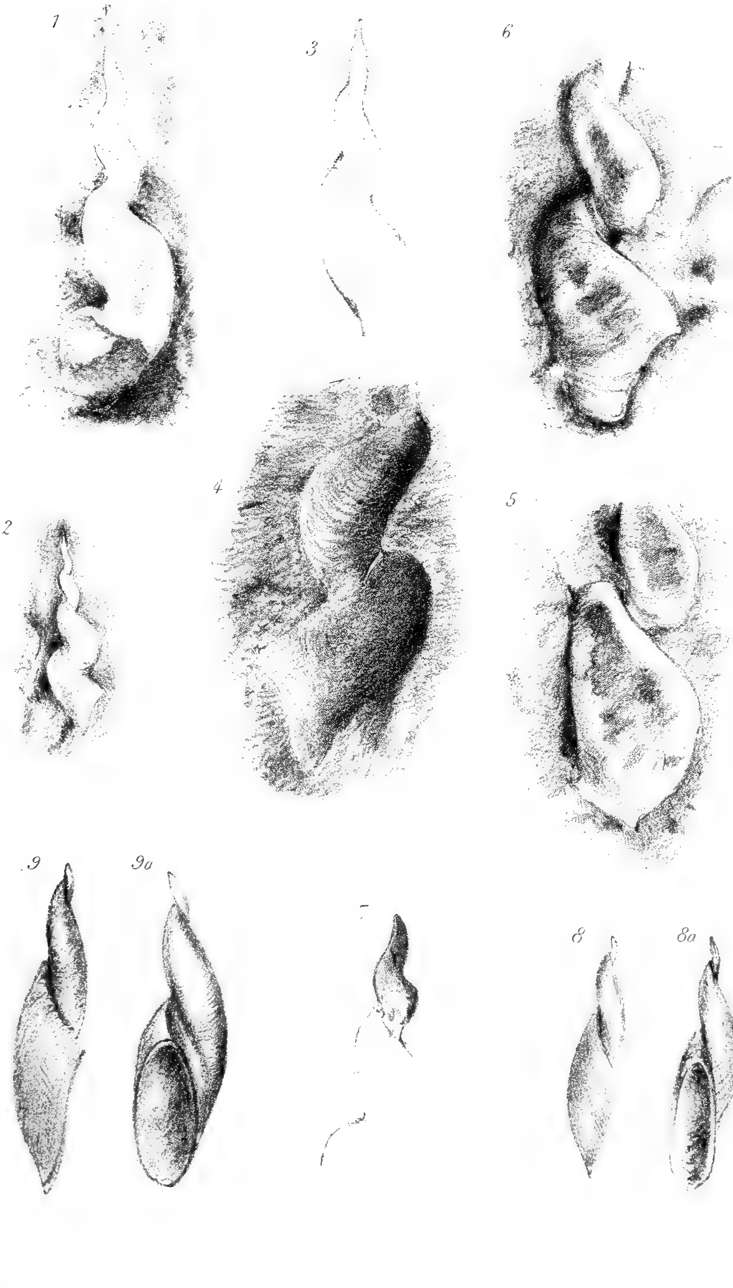
Similar to above, but the apex much shorter and blunter, and the whorls more compressed together.

		millim.		millim.
Size.	Major diameter	1·5	alt. axis	6·5
,,	recent species: *terebra*	3·0	,, vix	9·0
,,	,, var. *Austeni*	1·0	,, ,,	3·75
,,	,, *lineatum*	2·3	,, ,,	4·5

Some of the specimens are beautifully preserved, and are not mere casts; it is unfortunate that the aperture is more or less incomplete in every shell, although in the two pieces of stone I have seen there are over a hundred of them.

I cannot do better, to describe how and where it was found, than give an extract from Mr. Shrubsole's letter to me, dated 7th January, 1881:—"The shells did not come from the well, but from the higher level of the cliffs. I was showing a field-class how to look for fossils on the beach; and whilst we were standing in a group I was asked a question respecting the septarian nodules scattered about. After telling all I could about them, I stooped down and examined the broken one at my feet. Seeing a thin calcareous line near the surface of the nodule, with a blow of the hammer I exposed the shells; and I could not identify them: I brought them home. I gave away to those with me all I found beside." . . . . . "I cannot tell from what horizon in the London clay the nodule came, except that it must have been within the uppermost 150 ft."

No discovery could possibly show better what a broken chain geological evidence affords us of the extension and distribution of genera. Here one fortuitous blow of the hammer disclosed some dozens of a genus never before found, or rather recorded, as fossil in Europe,



H. H. Godwin-Austen, del et lith.

Maclure & Macdonald, imp

CAMPTOCERAS.

and one which even now is so locally distributed in the east that it has only been found living by three individuals, in two widely-separated spots. Mr. Shrubsole may be complimented and congratulated on having brought to light so interesting a fossil form.

EXPLANATION OF PLATE V.

Fig. 1.	*Camptoceras priscum*, n. sp., × 12. Length 4·2 millim.
2.	,, ,, × 4.
3.	,, ,, apex, × 12.
4.	,, ,, impression showing oblique aperture, × 12.
5.	,, ,, broken at the constriction.
6.	,, ,, var. *obtusum*, × 12.
7.	,, ,, do. apex. × 12.
8, 8*a*.	*Camptoceras terebra*, Benson, × 4,
9, 9*a*.	,, *Austeni*, H. F. Blanford, × 11.

Discussion.

Mr. Etheridge remarked on the interest of finding in Britain an Eocene freshwater shell of a genus now living only in India. The genus appeared to be near *Physa*.

Mr. Gardner said that it was interesting to find so remarkable a tropical form so high up in the London Clay. He thought there was evidence that the more tropical forms of fruits occur in the higher beds of the London Clay.

The Author was unable to say what genera of plants were found in association with this land-shell in India; but Canes, Palms, Ferns, and large grasses grow on the edges of the marshes.

24. *On the* Chalk-masses *or* Boulders *included in the* Contorted Drift *of* Cromer, *their* Origin *and* Mode *of* Transport. By T. Mellard Reade, Esq., C.E., F.G.S. (Read January 11, 1882.)

Though for many years engaged in the study of Drift, it was not until the summer of last year that I found my way to the cliffs of Cromer.

The sections to be seen along the Cromer coast have formed a stock subject with geologists since R. C. Taylor, in 1827*, and Lyell, in 1840†, wrote upon them. Nevertheless they are not likely to lose their interest; for the phenomena they present are so strange and striking, and so out of the usual run of drift sections, that he would be a very unimaginative geologist who failed to be impressed by them.

Since my return I have looked up the literature of the subject. Perhaps I ought to have done so first: but there is a certain advantage in one's mind being as a blank sheet; for then the impressions come direct through one's own eyes instead of being coloured by the views of others.

The result of this examination leads me to think there is still room for further description, as well as for a reconsideration of the origin and mode of transport of the so-called "Boulders," or Chalk-masses—a question that has been so far, it seems to me, treated in a very general, cursory, or inadequate manner.

The term "Boulder" is, of course, used by writers in its geological sense of a transported mass; but as in the vernacular it means a rounded and waterworn stone, the use of the term is very likely, without due warning, to create an image of something very different from what the Norfolk cliffs disclose.

As my object is not to reiterate, but rather to supplement the observations of preceding geologists, I purpose to confine myself as closely as possible to what I have personally seen and inferences therefrom, only incidentally discussing, as occasion arises, the various theories on the subject that have from time to time been broached‡.

* "On the Geology of East Norfolk," Phil. Mag. April, May, June, October, and November, 1827.

† "On the Boulder Formation of Eastern Norfolk," Phil. Mag. May 1840.

‡ The following are references to some of the principal writings relating to the subject in addition to those before quoted:—

Lyell's 'Elements of Geology,' 2nd. ed., 1841, vol. i., "On Norfolk Drift," pp. 226–236.

"Erratics of Norfolk," &c., Trimmer, Quart. Journ. Geol. Soc. 1851, pp. 19–38.

"Lincolnshire Drift," Morris, Q. J. G. S. 1853, p. 320.

On a "Section at Litcham," S. V. Wood, Junr., Q. J. G. S. 1867, pp. 84–87.

'Memoirs of the Geological Survey of England', 1875, "Geology of Rutland," Judd, pp. 245–249.

Ditto, ditto, "Geology of the Fenland," Skertchley, 1877, pp. 236–241.

The Geological Position of the Cromer Till and Contorted Drift.

The relations of the glacial beds to those below can best be seen by commencing at Weybourne and walking eastwards towards Cromer. The Chalk forming a basement bed for the whole of the Pliocene and Post-pliocene deposits, is here seen in the cliff. Resting upon it is a bed called "iron pan," composed of flints and shells, cemented together with ferruginous matter. Above this are a series of laminated sands and clays called, by Mr. H. B. Woodward, Weybourne Crag, and thought by him to be the upper part of the Norwich Crag, but considered by Mr. J. H. Blake to be the equivalent of the Chillesford Clay, and identical with that below his "rootlet-bed" at Kessingland*. Above the laminated sands and clays is a bed corresponding in appearance with the "rootlet-bed" at Kessingland; and upon it rests the Contorted Drift, which is not very striking at this end of the cliff section; but as we proceed towards Sherringham it comes in with greater force. The laminated sands and clays are to be seen at various points, even beyond Sherringham, forming the base of the glacial deposits, though, as the cliffs are so obscured by talus, I could not aver that their continuity was not broken in places; indeed, if we refer to Lyell's

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'Cambridgeshire Geology,' Bonney, pp. 69–76.

"Denudations of Norfolk," Fisher, Geol. Mag. 1868, pp. 548–553.

Presidential Address, Proc. of Norwich Geol. Soc., H. B. Woodward, Session 1878–79.

Ditto ditto, J. H. Blake, Session 1879–80.

"On a Disturbance of the Chalk at Trowse," Proceed. of Norwich, Geol. Soc. H. B. Woodward, pp. 109, 110.

"Sequence of the Glacial Beds," S. V. Wood, Junr., Geol. Mag. Sept. 1871.

'The Post Tertiary Deposits of Cambridgeshire,' A. J. Jukes-Browne, 1878.

"The Glacial Deposits of Cromer," Clement Reid, Geol. Mag. Feb. 1880.

"The Chalk Bluffs of Trimmingham," A. J. Jukes-Browne, Ann. & Mag. of Nat. Hist. Oct. 1880.

On the "Hessle Boulder-clay in Lincolnshire," A. J. Jukes-Browne, Quart. Journ. Geol. Soc. Aug. 1879; refers to *buried chalk cliffs*, p. 412.

"Disturbance in the Chalk of Norfolk," H. B. Woodward, Geol. Mag. Feb. 1881, p. 93.

"Classification of the Pliocene and Pleistocene Beds," Clement Reid, Geol. Mag. Dec. 1880, pp. 548, 549.

"On the Newer Pliocene Period in England," S. V. Wood, Junr., Quart. Journ. Geol. Soc. Nov. 1880.

"On a Displacement of the Chalk at Whitlingham," J. E. Taylor, Geol. Mag. 1865, p. 324.

"On a Disturbance of the Chalk at Swainsthorpe," J. E. Taylor, Geol. Mag. 1866, p. 44.

"On the Glacial Period in Norfolk and Suffolk," Thos. Belt, Geol. Mag. 1877, pp. 156–8.

Various references to the Post-Tertiary Deposits of Norfolk will be found in Lyell's 'Principles' and Geikie's 'Great Ice Age.'

"Physical Geology of East Anglia during the Glacial Period," Penning Quart. Journ. Geol. Soc. 1876, vol. xxxii. pp. 191–203.

It is unnecessary for me to give further references, as any one going through the above will find them given in one place or another.

* Pres. Address, Norwich Geol. Soc. Session, 1879–80.

paper "On the Boulder Formation of Eastern Norfolk" (Phil. Mag. 1840, p. 367), or to the 2nd edition of the 'Elements,' vol. i. p. 231 (1841), we shall see a sketch of an "included pinnacle of chalk" resting directly upon the "iron pan," at Old Hythe Point, west of Sherringham, in which no laminated beds are shown between the "till" and the "pan"*.

Between Sherringham and Cromer the Chalk, with the iron pan above it, in places was clearly exposed on the foreshore. There is evidently, as described by Mr. R. C. Taylor, in 1827†, a general dip of the strata to the south-east.

If after this we walk from Mundesley northwestwards towards Cromer, we shall find the Cromer Till here very chalky, forming the base of the cliffs, north-west of and close to the section of the famed Post-glacial river-channel.

Further on the base was obscured by talus; but as we approached the "Trimmingham bluffs" the Contorted Drift was disclosed at the shore-level; and if we refer to the paper of Lyell's already quoted, p. 358, we shall see a sketch showing the "laminated blue clay" or "drift" actually underlying the "protuberance of chalk" at its right-hand extremity (*a*, fig. 1)‡. Beyond this point and near to Sidestrand I saw clearly-exposed beds of flint gravel with laminated sand and clay, yellow, white, and blue; and still further on, reaching 10 feet

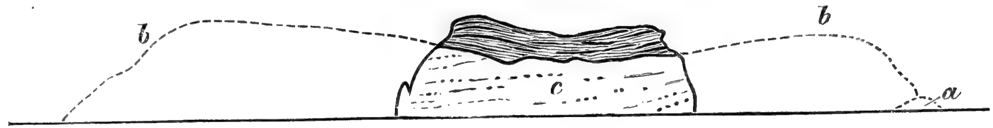
* In 1864 Sir Charles Lyell writes:—"Leonard and I have just returned from Sherringham, where I find that the splendid Old Hythe pinnacle of chalk, in which the flints were vertical, between 70 and 80 feet high, the grandest erratic in the world, of which I gave a figure in the first edition of my 'Principles,' has totally disappeared."—*Letter to Sir Charles Bunbury, Life of Lyell*, vol. ii. p. 441.

† Phil. Mag. 1827, p. 286.

‡ These "Bluffs" are usually considered to be connected with the Chalk below, as the Chalk is exposed on the foreshore at low water; and much ingenuity has been expended in explaining the "contortions" or disturbance they have undergone, as well as their exceptional appearance and position. I have searched the various sections in vain for any adequate proof that these Bluffs are connected with the Chalk below. The evidence is all incomplete. There are certain facts pointing to the probability of the Bluffs being boulders, such as their being, so far as we can see, imbedded in Contorted Drift or Till, while not far off on either side lie undisturbed preglacial beds rising above the level of high water. Lyell considered that the Drift and the Chalk had been simultaneously disturbed, which is consistent with the boulder hypothesis, but difficult otherwise to understand. He also thought that they formed part of a larger central nucleus of Chalk under Trimmingham beacon, and that as the sea cut the cliffs back the exposure of Chalk would increase; instead of that, the northern bluff has, since his observation in 1839, diminished in length from 106 to 37 yards, while one bluff has entirely disappeared. I have shown in dotted lines *b b*, in fig. 1, the size of the northern bluff as described by Lyell in 1839, and its present size, from a sketch by myself in 1881, in the same figure, *c*. Fig. 2 is the cross section as figured by Lyell; figs. 3 and 4 the end views as seen by me. Without in any way presuming to settle a matter which has puzzled such trained observers, all these facts, except the nearness of the Chalk on the foreshore, are to me more reconcilable with the boulder hypothesis than with any other. Those interested will see the case well stated by Mr. Jukes-Browne, Ann. & Mag. of Nat. Hist. Mr. Clement Reid's hypothesis that the chalk bluffs have been pressed up by an ice-sheet from seaward seems to me to introduce more difficulties than it explains.

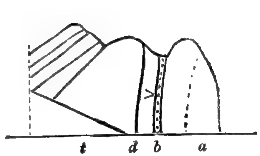
Figs. 1–4.—*Northern Chalk Bluff, Trimmingham.*

Fig. 1.—*Front view*, 1881.



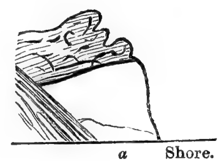
b b. As described by Sir Charles Lyell, 1839. *c.* As seen in July 1881. *a.* Drift.

Fig. 2.—*Lyell's Side-view*, 1839.



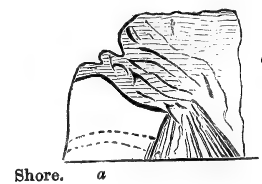
a. Chalk. *d.* Drift.
b. Gravel. *t.* Talus.

Fig. 3.—*Southern Side*, 1881.



a. Chalk. *t.* Talus.
d. Contorted Drift.

Fig. 4.—*Northern Side*, 1881.



a. Chalk.
d. Contorted Drift.

above the shore, were found a series of false-bedded gravels and sands, then laminated sand and clay capped by a dark loamy bed, together like those I have described as occurring above the "iron pan" at Weybourne.

Nearly opposite, a ferruginous pan was exposed on the shore; and still further to the north-west the cliffs clearly displayed 15 feet of false-bedded sands. It is not my wish to interfere in the controversies that have been raging of late among geologists in the neighbourhood of Norwich regarding these preglacial beds or "Forest-bed series;" but for the purposes of this paper I must state my conviction that the true Drift-beds appear to rest on a pretty well-marked eroded surface of the preglacial beds usually known as the Forest-bed series; and I see no reason to doubt that Mr. J. H. Blake * has at points, where eroded, discovered the remains of a true land-surface similar and equivalent to the "rootlet-bed" which, in his company, I saw remarkably well exposed at the base of the Kessingland cliffs. It is held by some that this "rootlet-bed" does not contain the roots of forest trees; but for our purpose this is a matter of no moment, as even if they were roots of ferns, which I doubt, it will be equally a land-surface and serve just as well for a base-line for our drift-deposits. That it was a land-surface, after the diligent investigation I have carried on for years on a parallel subject in my own neighbourhood, I have very little doubt; but it is quite possible that the upper part of the bed has been eroded, and that the rootlets we see are the tap-roots, as they are all vertical †.

I could parallel the rootlets pretty closely in certain stages of the denudation of the postglacial submarine forest-bed at the Alt mouth, Lancashire‡.

From the foregoing considerations it will be seen that I consider the lower part of the Cromer Till to represent the incoming of the true glacial conditions. Mr. Searles V. Wood puts the Crag at Weybourne with the glacial series, because it contains the shell

* Presidential address to the Norwich Geol. Soc., Session 1879–80, p. 146, by J. H. Blake, F.G.S.

† *April* 28, 1882.—This bed is described in a letter of Sir Charles Lyell to Sir Charles Bunbury in 1869. He says, "But I wished much I could have had the advantage of walking with you along the Kessingland and Pakefield Cliff, about 50 and 60 feet high, where, at the base for more than a mile, in a bed of what I formerly called green till, a homogeneous unstratified clay, I found upright plants or shrubs standing vertical, with their roots in the same green soil (apparently tap-roots), also vertical and a foot or more long. In one place, near Pakefield, this lower stratum was laminated, and contained prostrate flattened trees a foot or more in diameter. Over this green till, with plants *in situ* (of which I have kept a few specimens to show you), reposes stratified sand many yards thick, and over this drift, with plicated boulders of Chalk, Lias with fossils (*Avicula cygnipes*), numerous Ammonites, Belemnites, pieces of mica-schist, sandstone, greenstone, and other rocks. It is strange to see this glacial drift covering the bed for a mile and a half, with trees which must have grown *in situ*, and must have sunk down so as to allow first the sand and then the boulder-clay to accumulate over it."—*Life of Sir Charles Lyell*, vol. ii. p. 439.

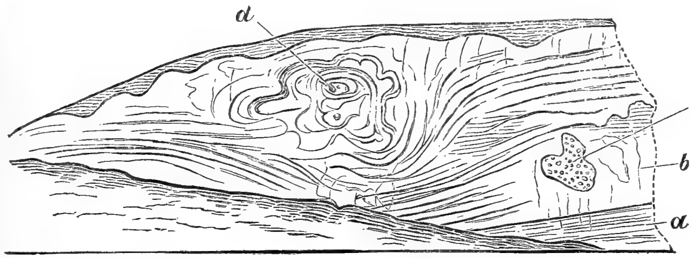
‡ Described in Quart. Journ. Geol. Soc. 1878, pp. 447, 448, and in various papers in the Proceedings of the Liverpool Geological Society.

Tellina balthica ; but I consider, with Messrs. H. B. Woodward, J. H. Blake, and Clement Reid, that the presence of this one shell is an unsatisfactory test of the climate being glacial. No doubt the climate was gradually changing; but I could see no evidence of ice-action below the till. The generally undisturbed nature of the Crag-beds negatives the supposition.

Description of the Cromer Till and Contorted Drift.

The lower part of the Cromer Till is, in places, stratified. This I distinctly noticed in more than one place; and it is shown in the section taken at right angles to the shore (fig. 5, *a*) between Sherringham and Cromer. In another place I noticed that the till rested

Fig. 5.—*Section cut out by a Stream at right angles to the shore between Cromer and Sherringham.*



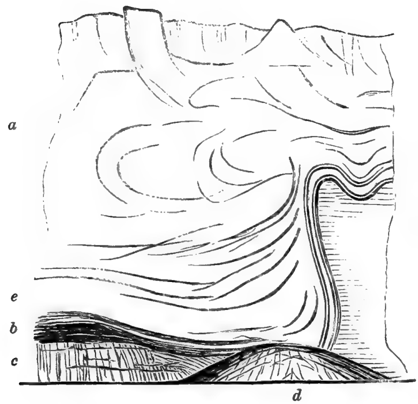
a. Stratified till.
b. Unstratified till.
c. Nest of gravel.
d. Contorted sands and gravels.

upon white stratified sand; and also at a point near Sherringham an eroded surface of black loam was capped by red gravel. It is not easy always to distinguish between the preglacial beds and the incoming glacial, especially when the base of the cliffs is encumbered with talus; and even where a vertical face is to be found, if not perfectly fresh, it frequently gets washed over with sand from above, rendering it necessary to scrape it down before its nature can be disclosed. Mr. J. H. Blake says*, " Where the unstratified rootlet-bed is to be seen, this line is very marked; but where the rootlet-bed has been entirely denuded, it is frequently not so well marked, from that and the following reasons. There are sometimes sands &c. immediately above and below this bed of a similar colour and nature, which, when the bed itself is entirely denuded, come together and give an appearance of a break in the series." The till may therefore be described as sometimes passing down into semistratified beds, itself being usually unstratified, but occasionally partially so, as we see is also the case with the marine Boulder-clays of West Lancashire. Upwards it usually passes into the Contorted Drift in an indescribably confused sort of manner, but occasionally displays a very

* Presidential Address, Norwich Geol. Soc., Session 1879–80, p. 147.

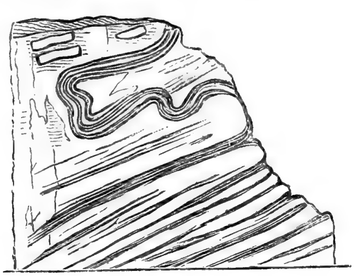
distinct line of erosion, which may be traced from Mundesley as far as the southernmost of the chalk bluffs. The Contorted Drift is a confused, folded-up mass of sands, gravels, and muds, which in places have been distinctly stratified and afterwards forced up and bent into the most striking convolutions (figs. 5, 6, 7). The confused arrangement of the beds is best illustrated by the section at right

Fig. 6.



a Contorted drift. *b b.* Till.
c. Talus. *d.* Mud talus.
e e. Stratified bands folded up and disturbed.

Fig. 7.—*Section between Cromer and Sherringham.*



angles to the shore (fig. 5) where unstratified till (*b*), containing a nest of gravel (*c*), rests upon stratified till (*a*), while horizontally the unstratified till passes into sands and gravels in an indescribable state of confusion not unlike the figure in a knotty piece of wood, as at *d*. The included boulders of primary rocks and the chalk-masses I shall treat separately, as well as the relations that can be traced between the convoluted beds and the included masses.

The contorted drift is capped by a series of sands and well-rolled gravels, which Mr. Searles Wood, with his usual accuracy, has shown

in a section illustrating a paper "On the Sequence of Glacial Beds" (Geol. Mag. Sept. 1871, p. 4 of reprint); but I agree with Mr. Jukes-Browne, and others of the Survey, in thinking that they do not lie in valleys of erosion. Mr. Wood calls these gravels "middle glacial," a term that has been very generally adopted; but Mr. Penning says * "If these views be correct, there is, between the Lower and Middle Glacial, no definite line of demarcation." As the object of this paper is not to discuss the nomenclature of the drift beds, I will pass on to a description of the chalk inclusions.

Included Chalk Masses.

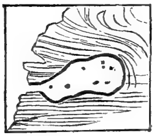
The simplest form of chalk inclusion is an irregularly shaped, partially rounded, isolated mass, as fig. 8, A and B; a still more irregular and angular form is shown in fig. 8, C, an instructive example of what happens to these masses when the base of the drift gets swept away by the sea. At first sight this looks like an isolated pinnacle, the part *c* standing out in relief from the cliff with talus at the base, *a*; further examination shows, however, that it is part of a mass 1, 2, 3, 4, 5, 6, 7, of which 5, 6, 7, 1, constitute a surface flush with the natural face of drift, this portion of the boulder evidently having split off through the removal of the drift from below. Fracture of the masses in this way is a frequent occurrence, arising from the incapacity of the chalk to support the weight of the superincumbent drift when partially undermined. This fact was well illustrated by a landslip I observed between Cromer and Sherringham, where a portion of a horizontal chalk-mass of considerable proportions had slipped down bodily onto the shore, and, though shattered, retained generally its relative position and form.

The next form of inclusion is an apparent aggregation of irregular masses, as shown in fig. 8, D, but which have really originally been one mass, afterwards separated, as shown in the sketch, the cavities being infilled with drift apparently folding round the masses and penetrating them in a very remarkable manner. Fig. 8, E, is an instructive example of how this separation develops and comes about. The larger masses of chalk, however, are distinctly characterized by length and horizontality, as shown in fig. 8, F, G, and in fig. 9.

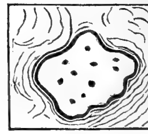
How horizontal masses of such longitudinal dimensions could be conveyed and imbedded in mud and sand with so little fracture is one of the suggestive problems presented for our solution. From the position of the boulders and the nature of the cliff it is no easy matter, nay, often impossible, to examine them closely; but it is plain to see that, as a rule, the junction of the external surface of the chalk with the drift in which it is imbedded is marked by laminated beds of the drift a few inches in thickness enwrapping the mass or boulder, as shown in the numerous examples figured. The most surprising feature about the boulders is perhaps the length and extreme tenuity some

* "On the Physical Geology of East Anglia during the Glacial Period," Quart. Journ. Geol. Soc. vol. xxxii. p. 195.

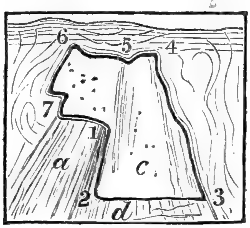
Fig. 8.—*Various Forms of Chalk-inclusions.*



A

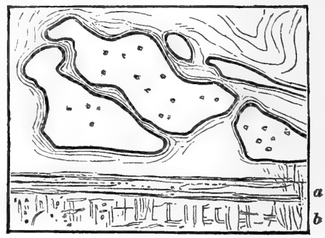


B



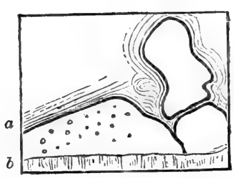
C

a. Talus.



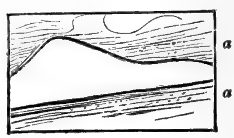
D

a. Stratified sand. *b.* Talus.



E

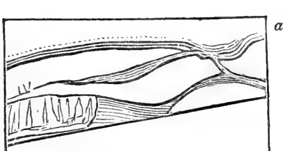
a. Stratified gravel. *b.* Talus.



F

a. Stratified sand.

G



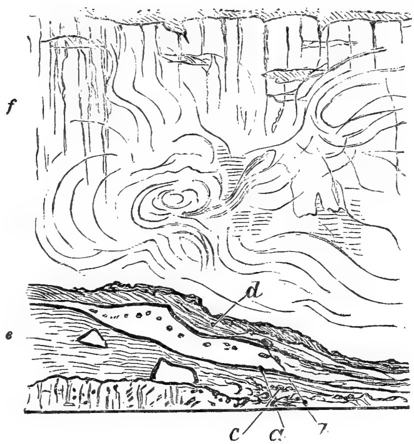
a. Gravel.

H

a a. Contorted drift.

of these masses attain, together with the remarkable way in which the continuity of the chalk is preserved without disruption. This characteristic interested me much; and fortunately one of the best-defined of the boulders of this form I found to be partially within reach. I saw this mass on three separate occasions, and eventually made a coloured sketch of it on the spot, which is reproduced in fig. 9.

Fig. 9.—*Chalk Mass between Cromer and Sherringham.*



a b. Beds of shells 2–3 inches thick.
c. Contorted beds of sand.
d. Stratified sands.
e. Till.
f f. Background of contorted drift.

It was about 120 feet long; I judged it to be about 12 feet in its thickest part, thinning out gradually northwards at its lower end, where I measured it, to only 9 inches. This part I could reach with my hammer, and found it to be solid compact chalk. The flints, as will be seen on reference to the drawing, follow the form of the mass, showing that it has been to some extent bent; but I could discover no fractures. But the most remarkable fact I have to record as bearing upon the mode of its transport is that, underlying it, at *a*, was a bed of shells about 2 or 3 inches thick, consisting of broken valves closely packed and crowded together, and above it was another and similar bed *b*. The mass lay at about the angle displayed in the drawing. Where these shells occurred the boulder was underlain by contorted beds of sand (*c*), and above by sands (*d*) rudely stratified in the direction of the upper surface. In addition to those I have described are larger masses of chalk marl. It is unnecessary for me to describe the "boulders" in greater detail. Lyell, in his paper in the Phil. Mag. 1840, shows also the lamination and folding of the drift in contact with the masses conforming to their outline. It must also be remembered that where the included masses do not occur in the drift, as at the extreme ends of the section described, it is much less disturbed and convoluted in its character.

Origin and Mode of Transport.

An attentive consideration of the forms and mode of occurrence of these masses will, I think, throw considerable light upon their origin. They have by various observers been attributed (1st) to diluvial currents, (2nd) to icebergs, (3rd) to land-ice either as a glacier or ice-sheet; but the subject is so difficult that most observers have contented themselves with these general statements, no attempt that I know of having been made to investigate the matter in detail. There is, I think, a general agreement among the older geologists that they have been floated into their present positions "somehow" by ice.

It is a striking fact, and one to be duly weighed, that only rocks of a certain nature are found occurring of these huge dimensions in the Drift. The harder and primary rocks, the sandstones, gneisses, granites, syenites and basalts never occur in this form; they may be found as rounded or cubical boulders of many tons' weight, but none of a size like these. In none of the sections in Lancashire are such masses found, nor are the beds of Drift contorted, though they are much fuller of far-travelled planed and grooved erratics and boulders and other indications of glacial action. Masses of Marlstone Rock-bed, of oolite, and of chalk and gault of enormous proportions have been described by Morris, Judd, Skertchley, Bonney, and others as found imbedded in the Boulder-clay in Lincolnshire, Rutland, &c.; but we find they possess this common characteristic: they are long, shallow, and narrow. They, in fact, are of just the form that would be taken by masses breaking off from a cliff or escarpment.

The geological formations from which they are derived are distinguished by possessing numerous springs; the beds are either entirely porous or they lie upon sands or clays*.

I take it for certain that the origin of such travelled masses of rock is to be sought in cliffs and escarpments. Then how could such enormous masses be conveyed to a distance from the parent rock. It stands to reason that the transporting agent, whatever it may have been, could convey them many miles as easily as one mile. Professor Judd considers that some of the boulders he describes from the Marlstone Rock-bed have travelled not less than 30 miles. Land-ice, I think, is out of the question; the effect of a glacier is to grind its bed into an impalpable mud; and I cannot conceive any means by which an ice-sheet could tear up masses from the bed of the rock it passes over and detach them in this way. An iceberg is only the detached termination of a glacier or sheet of ice; and the same difficulty applies to this mode of origin, with the additional difficulty of requiring a great depth of water for flotation transport.

The position of the shell-beds under and over the chalk boulder (fig. 9, *a*, *b*) appears to me to show conclusively that it has been

* Professor Judd says (Geology of Rutland, p. 265):—"The frequent alternation within the district under description of pervious beds of limestone and sand with impervious clays gives rise to numerous springs," &c.

quietly deposited in water. That a mass of this shape and form could be pushed up, enveloped in drift, by a Scandinavian or any other ice-sheet, and preserve its continuity undisturbed, appears to me to be all but inconceivable. If, then, these masses were detached from cliffs (which, as I have shown, their form and the nature of the rock of which they are composed would indicate), and if they have been floated to their present position, it follows that the depth of water in which they were rafted off cannot have been very great. The highest point of the Chalk in Norfolk is 650 feet*. The highest point from which the Marlstone Rock-bed masses can have been derived is from 700 to 800 feet.

The extreme limit of depth of water could therefore, when the last of these masses were quarried, not exceed 600 feet above the present sea-level. But we must not lose sight of the fact that from the sea-level the Chalk has a pretty gradual slope upwards from east to west; therefore as the land subsided the inshore waters would in all cases shallow towards the cliff.

It really then resolves itself into a question of "launching;" and when we are confronted with the fact that a mass of solid chalk in some cases as big as the Great Eastern has to be quarried out of the natural bed and quietly deposited with little derangement at the bottom of the sea or on the nearest submarine bank, it forms a problem for solution in geological engineering of a very interesting nature.

It is easy to see, in the case of strata like the Marlstone Rock-bed resting upon strata of a different nature, that ordinary landslips would detach masses from the parent rock, which might afterwards be conveyed by ice to a distance. But with regard to the Chalk the case is rather different. The masses in the Norfolk Drift appear to be homogeneous; so that an ordinary landslip hardly meets the case. We know, however, that the Chalk is full of potholes and fissures; and any crack that opened in the top of a cliff might be opened further by intrusive ice. Until last winter I never realized the fact that ice could be intrusive; but then I observed, and described in a letter to 'Nature,' how water held up in the sandhills and percolating therefrom could insinuate itself into hard peat in the form of ice, and split it off in great sheets, one of these I measured being 16 feet long, 8 feet wide, and 8 inches thick, as flat as a flagstone, and containing a wedge of ice throughout its whole superficial extent. In a similar manner I conceive the water held up in the porous chalk would insinuate itself into any latent fissure or line of weakness or joint, and, gradually increasing by percolation and by water from melting snow, force out and detach masses of enormous proportions; also such streams of water issuing from the chalk might freeze into accumulated masses of ice about the detached rock. Pack ice driven onto the shore and piled up over and around it, and then in winter frozen into a sheet or ice-foot, might assist the accumulation until a raft were formed sufficient to float off boulders of the largest

* Penning, Quart. Journ. Geol. Soc. vol. xxxii. p. 191.

dimensions*. That ice can accumulate on land in an enormous mass, not as a glacier, is well shown by W. H. Dall, in the description of what he saw in Alaska in the vicinity of Bering Straits†. After describing ice-cliffs with interstratified beds of clay and vegetable matter, rising in two faces about 30 feet high each, he proceeds to explain that about a mile from the sea the ice formed a ridge about 250 feet above high water, and observes:—"That is to say, it appeared that the ridge itself, two miles wide, and 250 feet high, was chiefly composed of solid ice overlaid with clay and vegetable mould." In conclusion, Mr. Dall says "the formation of the surrounding country shows no high land or rocky hills from which a glacier might have been derived and then covered with débris from their sides. The continuity of the mossy surface showed that the ice must be quite destitute of motion; and the circumstances appeared to point to one conclusion, that there is here a ridge of solid ice, rising several hundred feet above the sea and higher than any of the land about it, and older than the mammoth and fossil horse, this ice taking upon itself the functions of a regular stratified rock. The formation, though visited before, has not hitherto been intelligibly described from a geological standpoint. Though many facts may remain to be investigated, and whatever be the conclusions as to its origin and mode of preservation, it certainly remains one of the most wonderful and puzzling geological phenomena in existence."

* *April* 28, 1882.—Since this paper was written, Mr. H. B. Woodward, F.G.S., has kindly allowed me to read the proof of his forthcoming Survey Memoir on the Geology of the country about Norwich. In this he gives sections and a detailed description of the "disturbed chalk at Trowse." The pit in which the sections occurred is on a range of low hills bordering the river Yare. Two sections are given in parallel planes twenty yards apart. One (fig. 24) shows disturbed chalk with lines of flints bent upwards in a south-easterly direction, at an angle of from 35° to 40°, having a vertical south-easterly face, against which is banked up a mass of reconstructed chalk containing drift-pebbles. The other shows a disturbed mass of chalk containing sandy pockets, and having an irregular vertical overhanging face, against which the reconstructed material, consisting of contorted laminated loam and marl, rubbly chalk and sand, reconstructed chalk, &c., abuts, and is apparently forced underneath the overhang in a tongue-like form. Mr. Woodward satisfactorily shows that the disturbance is not of preglacial origin. He also says, "In the neighbourhood of Norwich the disturbed or glaciated chalk is seen in the pits bordering the rivers." It appears that these disturbances are of frequent occurrence in such situations. Mr. Woodward points out that mammalian remains are frequently found in the disturbed chalk; they include the mammoth, the red deer, and a species like the roe-deer. All these facts point to a subaerial origin; and the position of most frequent occurrence being the banks of river-valleys is very suggestive. It is here, by drainage through the strata, that the intrusive subaerial ice would be capable of splitting, wedging off, and disturbing portions of the chalk; and during this time it is quite possible the mammalian remains may have been introduced. As the land became submerged some of these detached masses might be rafted off in the manner I have described, while some few might remain at their place of origin. Mr. Woodward says (p. 137), "It has been hinted that the disturbance at Trowse might have been due to the ice having acted on some irregularity in the ground, impinging perhaps on an old cliff which formed a local bar."

† "Notes in Alaska and the vicinity of Bering Straits," American Journ. of Science, February 1881, p. 107.

This shows that ice may accumulate on land in a way we had none of us before realized; while, on the other hand, Mr. Trimmer points out that ice in an extensive sheet of considerable thickness may remain even submerged. He says*, "Sir Edward Parry found for miles along the coast near Melville Island a dark blue stratum of solid ice, imbedded in the beach at the depth of 10 feet under the surface of the water. 'The ice,' he says, 'had probably been the lower part of heavy masses forced aground by the pressure of the floes from without, and still adhering to the viscous mud of which the beach is composed, after the upper surface has in course of time dissolved.'"

Dr. J. Rae describes how at Repulse Bay, during the spring of 1847, boulders situated at low-water mark were frozen into floe ice, and, being lifted by the rise and fall of the tide (which was from 6 to 8 feet or more), became eventually encased in the ice, which he found by measurement to attain a thickness of more than 8 feet. In the spring, by the double effect of thaw and evaporation, the upper surface of the ice was removed, so that the stones that were formerly at the bottom of the sea now appeared in the surface of the ice as if dropped there from a cliff" (Arctic Manual, 1875, p. 651).

Mr. Osmond Fisher calculates (Geol. Mag. 1868, p. 550) that flotation cannot take place unless the earthy matter does not exceed one twentieth in bulk of the whole mass. If, therefore, a mass of chalk 600 feet × 60 feet × 60 feet is to be rafted off, it would require ice equal to 43,200,000 cubic feet, including the rock, to effect it, or a combined mass 1200 feet long by 600 feet broad and 60 feet thick. That such a raft is a possibility, it would be difficult to deny. With an ice-raft of this nature resting upon the inclined plane of a shore, and subject also to the lifting-power of the tides, it is not difficult to conceive how such a mass once set in motion would launch itself out to sea.

In some such way, I conceive, the puzzling "boulders" have been derived and transported; and it is readily realizable that, with a large superficial raft of ice, the melting-power of the sea-water acting on an extensive surface might soon cause them to founder. But in many cases the sinking has been very gentle; or the mass would be more fractured than it is. I conceive that frequently the boulder has sunk with a great bulk of ice attached to it. But the vertical displacement which such weights would undoubtedly cause is not in my opinion sufficient to account for all the contortions of the drift in which we find them imbedded. Sections figs. 5, 6, 7 will, I think, serve to convince the most sceptical that lateral force has had a great deal to do with the folding of the strata. I conceive that the Drift of Cromer formed a large submarine bank, and that the sea was sufficiently shallow to allow of the ice-rafts and their burdens often grounding.

If this be so, it is not difficult to see that the impact of a mass of ice and rock weighing one million two hundred thousand tons would be quite sufficient to disturb, bend, fold, and contort the stratified

* Quart. Journ. Geol. Soc. 1851, p. 22.

beds of yielding mud, clay, sand, and gravel. If such ice-masses with their burdens sank into yielding mud vertically, or were driven into it by lateral pressure, the melting of the ice encircling the boulder might account also for some of the contortions of the surrounding beds. I have shown that the drift frequently has an apparent stratification concentric with the surface of the boulder, and not only encircling, but frequently penetrating it.

The enclosing matrix of ice as it gradually melted would be mechanically replaced by particles of the surrounding drift; and in this way it is quite likely that the concentric foldings of the drift around the boulder were induced. It is also not unlikely that, if the chalk-mass were fissured ever so slightly by the fall or deposition on an uneven bed, percolation of water would, while removing the chalk in the walls of the fissure, introduce at the same time fine particles of drift, and so produce that remarkable interpenetration of the chalk with laminated drift we so frequently see, as well as assist to produce in these separated masses rounded contours (see fig. 8, A, B, D, E).

If the boulder was formed and conveyed as I suggest, the chalk, no doubt, at the time would be frozen hard through its entire substance. The gradual thawing of it would, I surmise, while producing a sort of disintegration of the particles, render it, under the pressure and weight of drift above, partially plastic. In this way we may account for the bending of the larger masses without fracture, as is often shown by the wavy line of flints they contain.

It was my good fortune to see a mass of chalk capped with drift that had slipped down onto the shore. Though shattered, it preserved its form; and I could quite believe that under favourable circumstances it might again be consolidated into firm chalk. But some of these masses, notably the one shown in fig. 9, are of such extreme tenuity that the only feasible explanation of their preservation intact appears to be this:—that, after deposition, the mass has been exposed on the upper surface to the action of the sea, which has thinned it, or dressed it off, into the shape we see, before the drift above was deposited upon it. The same figure seems to point to this conclusion; for underneath is a bed of closely packed shell-fragments, and above, on nearly the same slope, another. I can see no escape from the conclusion that the upper shell bed was deposited in this manner. The underlying one may have been disturbed by the deposition of the boulder, and so pushed up from an originally more level plane; and the contortions of the sand underneath would seem to point to this disturbance having taken place.

My conclusions may therefore be summed up in this way:—

That the travelled masses were derived from sea-cliffs; they were landslips aided by the penetration of water forming ice intrusive, in fissures, which forced and quarried them from the parent rocks.

That water issuing from subterranean sources accumulated in ice round the fallen masses, and then was united and frozen into the shore-ice.

That ice-floes driven onto this mass would often get frozen into

it, combinedly forming a raft quite capable of floating away any boulders we are acquainted with. That the natural incline of the shore, aided by the rise and fall of the tides, on the breaking up of the ice at the approach of summer, would be equal to launching into the sea the entire raft, which has probably in most cases floated off in water not more than a couple of hundred feet deep. The whole arrangement of the bank and the materials of which it is composed appear to me to point to shallow-water conditions during its formation.

The masses of Marlstone Rock-bed on the west side of the Oolitic escarpment have probably, as pointed out by Professor Judd, been derived from the highest points, in which case they would be floated into as much as 600 feet of water; one of them is stranded on Beacon Hill. They appear to be isolated objects, such as we should expect if they foundered in deep water without stranding, through the melting of the ice raft and consequent insufficiency of flotation-power. But the frequency of these boulders and their accumulation in the Cromer drift points to their progress having been arrested by the shoaling of the water and by stranding on a submarine bank.

Discussion.

Dr. Gwyn Jeffreys asked if the author had named the shells found, and pointed out the desirability of their being examined, especially with respect to *Tellina balthica.*

The President stated that Mr. Clement Reid had carefully collected all the shells of these beds, and that they would be described in a memoir of the Geological Survey.

Mr. Evans expressed his interest in the paper, and his admiration of the care with which the author's conclusions had been worked out. He referred to the Chalk of the Roslyn Pit near Ely, and to masses of transported Boulder-clay imbedded in softer material already deposited.

Prof. Judd said he agreed with the author in believing that such enormous transported masses must have been conveyed by floating shore-ice, and could not have been carried by any form of land-ice or iceberg.

Mr. Drew thought that the author's views were well worthy of consideration. He had himself seen in Tibet spring-water accumulating and freezing till it formed masses of ice many acres in extent and from 8 to 10 feet thick, which appeared to last all through the summer.

Rev. E. Hill found it difficult to understand how the rock-masses could be separated from cliffs without being overturned.

Prof. Hughes said that he had himself seen agencies at work in this country which, on a slightly larger scale, would explain all the phenomena described by the author. In the landslips near Lyme Regis, in the Isle of Sheppey, and along the river Clwyd, masses of rock and drift slide down without being much disturbed, and often remain right side up. Then, as to transport, he had seen

last winter in the estuary of the Dee masses of snow-laden shore-ice packed under the action of stream and tide, and frozen into one solid mass 12 feet thick, so that large vessels were icebound. When this broke up, ice rafts were formed some hundred feet in length and capable of carrying an enormous load of rock. The separate layers were often full of stones, sand, &c., which must have settled down irregularly when the ice melted.

Prof. Bonney said that such falls of rock now took place in the Arctic regions before the breaking up of an ice-foot. He thought the nature of the fragments in English Boulder-clay pointed to their being shallow-water formations.

Mr. Clement Reid, in reply to a question from Mr. B. B. Woodward, said that the chalk, from its fossils, had evidently been derived from no great distance. He added that the fossils in the sands lying on the boulders referred to are all fragmentary, and he did not regard them as contemporaneous with the deposition of the beds, but as derived from an older deposit.

25. *On some* Sections *of* Lincolnshire Neocomian. By H. Keeping, Esq., of the Woodwardian Museum, Cambridge. Communicated by W. Keeping, Esq., M.A., F.G.S. (Read February 22, 1882.)

During the excavations in some of the heavy cuttings required for the Louth and Lincoln railway I had the good fortune, in 1872, to discover a rich locality for the fossils of the Ironstone of this district. The fossils found were deposited for the most part in the Woodwardian Museum, though some were contributed to other collections.

I have revisited the locality at various times, once in company with my son, Mr. W. Keeping, M.A., now of York Museum; so that I have had good opportunities for the study of the fauna of these beds.

As it has been suggested to me that the cuttings must be getting obscure, through the growth of grass on their slopes, and that it would be desirable to put on record the facts observed, I again last summer visited the railway-cuttings and also the excavations for iron-ore near Claxby. The state in which these openings now are, the rapid way in which the beds are becoming hidden by overgrowth, has convinced me that the notes which we have made on the exposures may probably be worth preservation, notwithstanding their incompleteness. They are offered therefore without hesitation, but at the same time with a full sense of their partial and cursory character.

The Neocomian beds of the district have been well described by Professor Judd in his essay "On the Strata which form the Base of the Lincolnshire Wolds" *; indeed to this important work we owe our knowledge of the three members of the group, the fossil fauna of the limestone or middle divison, and even its separation from the Jurassic deposits, with which it seems to have been formerly confused. There is the less need therefore for any formal description; and I shall limit myself to a few remarks on excavations made since 1867, and on fossils supplementary to Professor Judd's list.

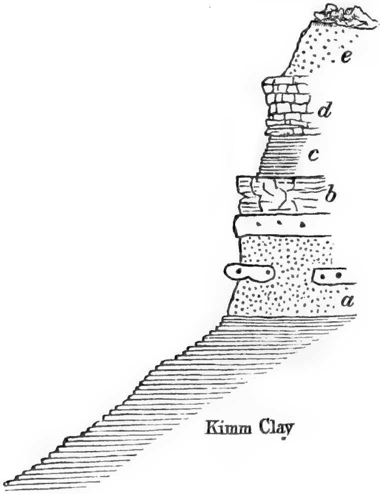
In the paper referred to (*l. c.* p. 243) the Neocomian beds are divided into:—1. Upper ferruginous sands; 2. Tealby series, alternate beds of sandy clay and limestone; 3. Lower sand and sandstone. They were well seen at the workings for iron-ore near Claxby. The works are suspended at present so far as the iron-ore is concerned; the mining is effected by an adit driven into the side of the hill, in the thickness of the iron deposit.

The iron-ore beds, about 9–13 feet thick, are extremely rich in fossils, but in a bad state of preservation.

* Quart. Journ. Geol. Soc. vol. xxiii. pp. 242–257 (1867).

In ascending order (see fig. 1), at the base is Kimmeridge Clay. This is well seen here, the junction with the Lower Sands and Grits being exposed at that portion of the excavation where they are now digging sand for the foundries and in the tram-incline. The uppermost beds are laminated bituminous flaggy shales, the "slaty and shaly bed" of Prof. Judd (*l. c.* p. 248). They are blackish-brown in colour; they have the characteristic appearance of bituminous Kimmeridge shales, and contain several distinctive fossils, such as *Belemnoteuthis antiquus*, Pearce, *Ammonites biplex*, Sow., fine var., *Discina latissima*, Sow., also a *Posidonomya*, *Pecten*, and *Astarte*.

Fig. 1.—*Diagram of Claxby Ridge.*



a. Lower Grits and Sands. *b.* Ironstone. *c.* Grey clay with nodules. *d.* Tealby Limestone. *e.* Upper Sands.

Below the hard flaggy shales are strong sticky grey clays. There are fully 250 feet (by barometric measurement) of these Kimmeridge beds down to the floor of the valley by the railway.

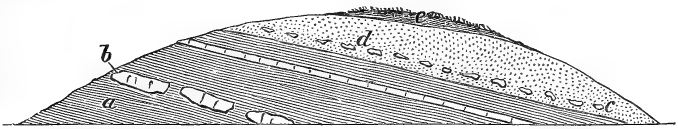
In places at junction with the Neocomian sand phosphatic nodules may be found at the base of the latter.

The Lower Sand and Grits (*a*) consist of various shades of greenish and brown-green: the sands are coarse and contain the black-coated grains so common in the Carstone; sometimes the sands are mottled with spherical brown patches, which in the consolidated sand-rock weather out with concentric structure, as mentioned by Prof. Judd (*l. c.* p. 248). The bands of grit in the sand are rather discontinuous. At the top of the sands is one bed about 2 feet thick, which is fairly constant all along the terraced ridge from Nettleton: it is fossiliferous; but the fossils are difficult to extract

when the bed is hard; and if soft, the test is usually dissolved, and only a mould remains.

The junction of the lower sands with the Kimmeridge Clay was also well seen in a cutting a few hundred yards E. of S. Willingham station (fig. 2). Here the greenish sands, where they lie on the flaggy Kimmeridge shales, contain at their base a line of phosphatic nodules.

Fig. 2.—*Diagram of Railway-cutting, E. of S. Willingham Station.*



a. Kimmeridge Clay. *b.* Line of Septaria. *c.* Line of phosphatic nodules in *d.* Lower Sands. *e.* Surface soil.

In the memoir referred to, it is suggested (*l. c.* p. 248) that about Market Rasen the lower sand and sandstone formed extensive rabbit-warrens and fir plantations, some of which have been brought into cultivation. We are however of opinion that these tracts are covered by a sand of quite a different description, viz. a member of the drift series; we think a consideration of the level up to which the Kimmeridge Clay occurs above the valley—over 200 feet, will make this apparent; moreover the last-mentioned sands differ lithologically in a marked manner from the Neocomian sands.

These lower sands in the excavations near Claxby are 24 feet thick. The fossils obtained from them are the following:—*Belemnites*, sp., *Ammonites Kœnigi*, Sow., *A. plicomphalus*, Sow., and others; species of *Chemnitzia*, *Phasianella*, *Pleurotomaria*, *Trochus*, *Crepidula*, *Pileopsis*, and *Natica*; *Pecten Cottaldinus*, d'Orb., *P. orbicularis*, Sow., *Cucullæa donningtonensis*, Keep., MSS., *Cardium subhillanum*, Leym., *Trigonia Keepingi*, Lyc., *T. tealbyensis*, Lyc., *T. ingens*, Lyc.; species of *Inoceramus*, *Avicula*, *Arca*, *Tellina*, *Lucina*, *Cytheræa*, *Thetis*, *Astarte*, *Myacites*, *Pholadomya*, *Lithodomus*, &c.

Above them is the iron-ore (fig. 1, *b*), an argillaceous ironshot limestone, *i. e.* full of dark-brown oolitic grains of iron oxide, with some streaks nearly all clay and devoid of the iron grains. This set of beds is 9–10 feet thick, and may be followed in the escarpment all the way from the north or Nettleton end of the ridge.

The two terraces of the escarpment formed by the harder beds are a marked physical feature of this ridge.

The fossils of the Ironstone differ somewhat considerably from those of the clays and limestone above, and are much more numerous. They are included by Prof. Judd in his "Tealby Series." The following is a list of them:—*Belemnites lateralis*, Phil., *B.*

quadratus, Röm., *Belemnites*, sp., *Ammonites noricus*, Schl., *A. plicomphalus*, Sow., and several other species; *Pleurotomaria neocomiensis*, d'Orb., *Pleurotomaria*, sp.; species of *Trochus*, *Turbo*, *Neritopsis*, and *Emarginula*; *Pileopsis neocomiensis*, Gardn., *Ostrea frons*, Park., var. *macroptera*, Sow., *Exogyra sinuata*, Sow.; *E. Tombeckiana*, d'Orb.; *Pecten cinctus*, Sow.; *P. striato-punctatus*, Röm.; *Pecten*, sp.; *Avicula macroptera*, Röm.; *Lima Tombeckiana*, d'Orb.; *Lima*, sp.; *Trigonia ingens*, Lyc.; *Astarte robusta*, Lyc.; species of *Modiola*, *Cucullæa*, *Tellina*, *Astarte*, *Mactra* (?), *Sphæra*, *Cyprina*, *Myacites*, *Pholadomya*, and *Sowerbya*; *Serpula lophiodes*, Goldf.; *S. gordialis*, Schl.; *Nucleolites*, sp.*

Above the Ironstone are seen at least 18 feet of grey clay (fig. 1, *c*), with scattered nodules containing macrurous Crustacea (*Meyeria magna*). These clays are fairly fossiliferous; but dry weather is required for collecting from them.

Near Donnington station is a brickyard exhibiting similar clay, 30 feet in thickness, containing *Belemnites lateralis*, *B. jaculum*, *Exogyra sinuata*, *Meyeria magna*, and *Serpula*. This greater thickness of clay seems counterbalanced by an absence of limestone here.

I regret that my notes are imperfect as to the limestone above (fig. 1, *d*); and details as to the precise thickness of the clays interbedded with the Grey Limestone are wanting; but, from a barometric observation made during the last visit, I conclude that between the last bed and the top of the Grey Limestone 35 feet of beds intervened, and above the limestone were about 15–25 feet of the unfossiliferous Upper Sands (*e*). In former years these upper beds were much better exposed than they are at present at Claxby.

The above section gives a thickness of the Neocomian here of 113 feet.

List of Fossils from the Clay and Limestone.

Belemnites jaculum, Ph.; *B. lateralis*, Ph.; *Belemnites*, sp.; *Ammonites Carteroni*, d'Orb., var.; *Crioceras asterianum*, d'Orb., var.; species of *Rostellaria*, *Scalaria*, *Actæon*; *Pecten cinctus*, Sow.; *P. orbicularis*, Sow.; *Pecten*, sp.; *Avicula* or *Inoceramus*; *Perna Mulleti*, Desh.; *P. Ricordiana*, d'Orb.; *Lima longa*, Röm., and several others; *Trigonia Robinaldina*, d'Orb.; *T. Keepingi*, Lyc.; *T. alæformis*; *Trigonia*, sp.; *Cyprina angulata*, Sow.; *Pholadomya Rauliniana*, d'Orb.; *Pholadomya*, sp.; species of *Arca*, *Nucula*, *Astarte*, *Myacites*, *Panopæa*, &c.; *Holaster*, sp.; *Meyeria magna*.

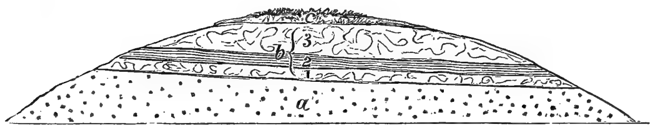
So-called red chalk forms the next succeeding bed.

* (*Note added on proof.*) The following species of Brachiopoda were collected from the Ironstone, but were mislaid and forgotten for a time:—

Waldheimia tamarindus, *Sow.*, var. tilbyensis, *Dav.*
—— Walkeri, *Dav.*
—— faba, *d'Orb.*, non *Sow.*
—— hippopus, *Röm.*, var. tilbyensis.
Terebratula sella, *Sow.*
—— depressa, var. cyrta.
Terebratula depressa, *Lam.*
—— prælonga, *Sow.*
Rhynchonella multiformis, *Röm.*
—— Walkeri, *Dav.*
—— lineolata, *Ph.* ?
—— speetonensis, *Dav.*

On the Lincoln and Louth railway is a cutting (fig. 3), near Benniworth-Haven House, which shows a thickness of 20 feet of sands, surmounted by the Ironstone about 9 feet in thickness. From the latter I have obtained a richer suite of fossils than from anywhere else in the district; they are not equally fine throughout the deposit, but are best preserved in a seam near the base.

Fig. 3.—*Sketch of Benniworth-Haven Cutting.*



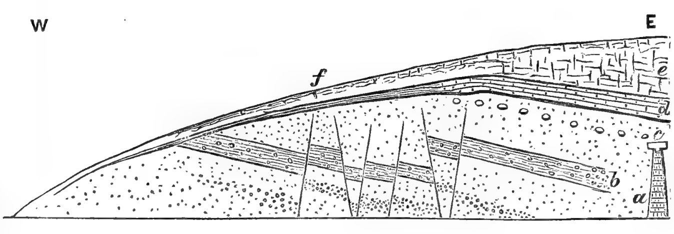
a. Lower Sands. *b.* Ironstone. *c.* Soil with flints from the drift.

For the accompanying sketch of Benniworth-Haven cutting I am indebted to Mr. W. Keeping, M.A. Three divisions of the ironstone may be noted, viz.:—(1) the better bed as described; (2) lighter-coloured, more argillaceous, and with cuboidal fracture; (3) brown crumbling stone.

The Upper Sands are usually said to be unfossiliferous; we have been also unsuccessful in finding fossils therein, except in the phosphatic nodules; these are fragmentary, probably derived, and scarcely specifically determinable. The following genera, however, occur—*Ammonites*, *Pleurotomaria*, *Requienia*?, *Modiola*, *Cyprina*?, *Myacites*, *Pholadomya*?, and *Pholadidea*. Lithologically, these nodules agree exactly with those from the Neocomian beds of the Bedford and Cambridgeshire area.

The Upper Sands are well seen in the cutting at the west end of Withcall tunnel (fig. 4).

Fig. 4.—*Sketch of Cutting at West End of Withcall Tunnel.*



a. Brownish and reddish-brown sands. *b.* Band of phosphatic nodules.
c. Line of ferruginous concretions. *d.* Red Chalk, 9 feet.
e. Greyish-white chalk, 8 to 15 feet above the tunnel.
f. Rearranged red and white chalk.

Fully 30 feet of the Upper Sands are here exposed; they are very

ferruginous, reddish-brown in colour, and contain scattered phosphatic nodules in a broad band as indicated in the sketch.

The sands vary in coarseness in different layers; in some the rolled quartz is larger than peas; the black pebbles and grains so common in the Potton district and in the Norfolk Carstone are also abundant.

At first sight it would appear as if in this section the Red Chalk (Hunstanton Chalk) were unconformable to the Neocomian; but it is not so; otherwise the White Chalk would have to be considered unconformable to the Red. The appearance of the Chalk not being affected by the slips which have dislocated the sands, and the apparent overlapping of the Chalk, are merely local effects due to the form and slope of the hill in combination with denuding action causing a slight rearrangement.

The difference between the Red Chalk of this section, which is on the horizon of that of Hunstanton, and the pinkish chalk of the Louth area, which is seen to the east of this tuunel, has been well pointed out by Prof. Judd.

Discussion.

Mr. Tawney remarked on the importance of the discovery of well-preserved fossils from the Benniworth-Haven cutting. He agreed with Mr. Keeping as to the age of the sandy beds near Market Rasen.

Prof. Seeley asked if the section did not contain representatives of the Kimmeridge, Portland, and Purbeck, as well as Neocomian. He remarked that the Portland, as it passes northward, loses its calcareous characters, and becomes sandy in character. William Smith appears to have regarded these beds as being of Portlandian age.

Prof. Judd remarked that we were greatly indebted to the author for detailed descriptions, with lists of fossils, of railway-cuttings which will soon be overgrown and rendered obscure. He noticed the remarkable absence of forms of Brachiopoda from the localities examined by Mr. Keeping, while he had himself found a considerable number of very curious and characteristic Neocomian forms*. He stated that, in the district where his own section was drawn, downwash from the Lower Sand and Sandstone covered considerable areas of the Kimmeridge Clay. In reply to Prof. Seeley he stated that the fossils of the Tealby Series agree most closely with those of the Middle Neocomian of the Continent.

* See footnote, p. 242.

26. *On the* Upper Beds *of the* Fifeshire Coal-measures. By Edw. W. Binney, Esq., F.R.S., and Jas. W. Kirkby, Esq. (Read January 25, 1882.)

[Plate VI.]

Overlying the profitable portion of the Fifeshire Coal-measures there is a series of red barren beds, of which we have not seen any description. Possibly Mr. Howell refers to similar measures, as occurring in Mid Lothian, in the Edinburgh memoir of the Geological Survey (pp. 110, 111); and since the date of that memoir an upper series of beds, evidently identical with that of Fife, has been recognized by the Geological Survey in Lanarkshire, and described as a separate subdivision (*d*5') of the Coal-measures *.

The best exposure of these red measures in Fife is on the coast from the mouth of the Leven to East Wemyss. Having somewhat carefully examined this section, we shall notice it briefly in detail—first as to the succession of strata, and afterwards as to the fossils found in them—and so give some account of the series.

The section in question forms part of the Wemyss coal-field, which, with the smaller adjoining fields of other lairds, is the most northerly piece of true Coal Measures existent in Britain †. The dip of the strata is easterly, rarely exceeding 10°, generally less; and as the trend of the coast is north-east and south-west, a section in descending order is to be observed by traversing the shore from the Leven westward.

The highest rock seen near the Leven is a red and purplish sandstone, which is well exposed opposite to the village of Innerleven, and which extends westward 600 yards or more, near to Methil. It is a softish rather fine-grained rock, lying apparently rather flat, though the amount of inclination is not always easy to see, owing to irregular bedding At the lowest water of spring tides it is seen extending seaward; so that its full thickness is evidently not shown. Towards the west it is usually more or less covered with sand; and it is only after storms or the prevalence of certain winds that this portion of it is exposed. Its thickness is estimated at fully 200 feet.

(This sandstone is considered to be part of the Coal-measures, as it apparently dips with the underlying beds; but we have observed no fossils in it, and it may possibly belong to a later formation. It is certainly the highest palæozoic rock (sedimentary) seen in Fife; and it may be assumed that still higher measures may come into the dip, seaward, beneath the Firth of Forth, that may be Permian.)

About 12 feet of soft red marl lies below the sandstone; but it is rarely seen. From beneath it rises a red marly sandstone of very

* Explanation of Sheet 23, p. 17; and of Sheet 31, p. 11.

† The great bulk of the coal wrought in Fife comes from the middle portion of the Carboniferous-Limestone series, and in quality it is fully equal to that obtained from the true Coal-measures.

irregular structure, and full of light-coloured slightly calcareous concretions. It passes underneath into a bright red false-bedded sandstone, which ranges behind and beneath the east pier at Methil. The fairway of the harbour is said to occupy the place of a soft stratum which we have not seen. Then comes in the thick mass of red sandstone (stained with yellow at the top) that forms the Beacon Rock to the west of the fairway. This sandstone is fully 30 feet thick, thus making nearly 290 feet of measures from the commencement of the section.

Following come about 100 feet of marl, fireclays, and shales, with thin sandstones, all of which are more or less red in colour. The marls are often marked with green spots, and contain calcareous concretions; and the fireclays are, in places, variegated with yellow and purple. Remains of plants occur in some of the beds *.

Below the latter series of strata is about 8 feet of purple and grey sandstone, which is hard and calcareous. Afterwards come 20 feet of red and grey shale and fireclay, with two thin and very coarse coals or black bands, and several thin bands of argillaceous limestone. The remains of fish, Limuloid crustacea, and plants are found in these beds.

Two or three feet of calcareous sandstone follow, and then nearly 50 feet of red, pink, purple, and grey shale, enclosing three or four bands of argillaceous limestone and a thin bed of sandstone, having for base a bed of hard red and greenish calcareous sandstone, from two to three feet thick, and of very irregular bedding and structure. In these beds occur the remains of fish, mollusca, and plants.

The rocks we have noticed west of the Beacon rock at Methil are all seen in irregular succession within a distance of 600 yards of the harbour.

A series of faults then disturbs the sequence of the strata, and causes many repetitions of some of the beds. At one or two places lower strata are seen, as a little to the west of Muiredge Den, where a thick red marl (with green spots) and some yellow sandstone are seen underlying the bed of hard calcareous sandstone. The disturbed ground continues to near the west end of Buckhaven Links, where, on the west side of a large fault, the two thin coals with shales, and a thick red sandstone † overlying (forming the rocks known as the Broadhills), are thrown again into section, and seen for the last time.

Between the point last named and Buckhaven the strata are

* In some of the fireclays are cylindrical pieces of grey limestone from 10 to 12 inches in length and an inch in diameter, resembling in form the rootlets of *Stigmaria*, and occurring in a vertical position. One of them, on analysis, gave :—

Carbonate of lime	50·61
Alumina	16·29
Magnesia	17·57
Silica	6·16
Oxide of iron	0·47

† Apparently the sandstone No. 27 of detailed section (p. 253) locally thickened.

masked by sand, except at one place, where the three-foot bed of calcareous sandstone comes up and forms a narrow reef. At the east end of Buckhaven the rocks again come to the surface, and form a continuous section westward. The first rock seen is a yellow sandstone, which is considered to be the same as that observed below the red marl west of Muiredge Den. About four feet of red marl underlies it: and then follows a thick bed of light red sandstone. This latter rock is coarse and gritty, and contains white quartz pebbles.

Repeated alternations of sandstone and shale and fireclay follow; and these form the rocks that are exposed in front of Buckhaven. The sandstones are yellow, red, and purple; and the fireclays (which prevail) and shales are red, purple, yellow, and white, and often finely variegated. Two bands of ochre occur in the upper portion of this series; and in other places some of the fireclays are very ochreous. The thickness of this set of beds is 100 feet. One of the shales contains the remains of *Calamites*; but as a rule the beds appear to be unfossiliferous.

Immediately to the east of Buckhaven Harbour a thick reef of sandstone rises from under the strata just noticed. This rock is red, purple, and whitish in colour, soft and thick-bedded, rather coarse and pebbly towards the base; and it is about 30 feet thick. Within the harbour are numerous strata of red, yellow, and white shale or fire-clay, and red and white sandstone, some of which are seen in the low cliffs just above the west pier.

For 500 yards or more west of Buckhaven the prevailing rock is fireclay, with here and there thin and irregular beds of sandstone. The latter are red and yellow in colour. The fireclays are red, purple, yellow, and white, of various bright shades, and most beautifully variegated *. These beds (which lie very flat) are estimated to be about 130 feet thick.

A thick mass of red sandstone now comes to the surface, and continues in section for nearly a mile, owing to the trend of the coast being here almost parallel with the strike. This rock is soft, sometimes coarse, and with pebbles of quartz and shale, laminated in places, and much false-bedded. Its thickness is apparently not less than 100 feet. It is well exposed both between tide-marks and in the cliffs to the east and west of East Wemyss.

To the west of East Wemyss, below the red rock, the measures take more the appearance of coal-bearing strata; and further on still, near to West Wemyss, workable coals come to the surface; but to these measures we need not at present allude, as we look upon the thick red sandstone last described as the base of the upper group of beds.

From the red sandstone at the mouth of the Leven to the red sandstone at East Wemyss there appears to be a thickness of over 900 feet of strata, with possibly other still higher beds continued beneath the sea.

* After a gale, when these fireclays have been swept bare of sand, the colouring is something gorgeous.

These upper beds are again seen on the coast to the east and west of Largo Harbour; but the section is not so consecutive or so extensive as the one we have noticed. Occasional outcrops of some of the beds are also to be seen by the sides of the dens that run inland from the coast. In former times various sinkings were made in them to the ochre-beds, which mineral appears to be the sole commercial product of the series; and the working of it is now abandoned.

Quite recently the Fife Coal Company have sunk through over 500 feet of these red measures near to Leven, and very successfully won the Chemise Coal at a depth of 870 feet from the surface. The section penetrated at these pits commences in the red shales (No. 47, p. 254) lying some little distance below the thin coals to the west of Methil, about 430 feet beneath the top of the sandstone at the mouth of the Leven, thus indicating an aggregate thickness for these beds about the same as we have arrived at for the coast section *.

In Lanarkshire and Ayrshire the Geological Survey have observed a slight unconformability between these upper beds and the ordinary underlying Coal-measures. We have not noticed any such break in the succession of the Fifeshire strata.

Note on the Calcareous Beds and thin Coals west of Methil.—The limestones which characterize this portion of the section are all thin and more or less impure. Some perhaps would be more properly termed marlstones, on account of the predominance of argillaceous matter in their composition. They are usually red or purple in colour, hard, compact, and with an even fracture. Sometimes they are grey and of an earthy texture; and where very impure they show cone-in-cone structure. All of them are very inconstant in thickness; and they thin out or run together within very short distances. The latter is the case with beds 39 and 41 (see detailed section, p. 254), which at high-water mark form a stratum fully a foot thick. This limestone has the surface very curiously marked with large concentric ripples or corrugations. Others have a blistered or flatly mamillated sort of surface. Four of the beds which have been analysed give 30, 38, 41, and 60 per cent. of carbonate of lime. The strata associated with the limestones are commonly more or less calcareous. The sandstones often effervesce freely on the application of acid; and the argillaceous beds in many cases are marls rather than shales or fireclays.

With these calcareous beds occur the two carbonaceous bands that we have termed coals. They are very thin and very coarse. Towards high-water mark, where they are about six feet apart, they do not exceed three inches in thickness. Both of them rest on fireclays full of rootlets. The lower band is overlain by a limestone; the upper band has a shale roof, highly charged with plant-remains near the coal. Towards low-water mark the former becomes more like a true coal, and thickens to over six inches; and

* We are indebted for this information to the courtesy of Mr. Charles Carlow, the general manager of the colliery.

at extreme low water the upper seam passes into black-band ironstone, eight inches thick, and charged abundantly with the carapace-valves of *Leaia* and other Entomostraca. These are the only carbonaceous and ferruginous beds that we have seen in the whole section from the Leven to East Wemyss, nothing so black being again met with until the ordinary coal strata are reached beneath and to the west of the thick red sandstone at the last-named place.

Palæontology of the Beds west of Methil.—The highest bed in which we have detected fossils is the shale No. 12 (see detailed section, p. 253), 30 feet below the West Beacon, which contains Stigmarian rootlets.

In the marl No. 16 there occur imperfect specimens of *Neuropteris* sp., *Lepidodendron* sp., and large fern-stems.

In the red marl and shale No. 24 there are abundant but very imperfect remains of an *Alethopteris* (leaflets nearly of equal size, strong midrib, with nervures nearly at right angles to it).

Bed No. 26 contains *Calamites*, Stigmarian rootlets, and other obscure remains of plants.

The next fossiliferous zone is the roof of the upper thin coal, which has yielded the following species:—

Ctenacanthus hybodoides, *Egerton.* Megalichthys Hibberti, *Ag.*, teeth. Strepsodus sauroides, *Huxl.*, teeth.	Fish.
Bellinurus trilobitoides, *König.* Eurypterus mammatus, *Salter.* Prestwichia anthrax, *H. Woodward.*	Crustacea.
Anthracomya, sp. nov.?	
Annularia longifolia, *Brongn.*	
Calamites Suckovii, *Brongn.*	
Cordaites, sp.	
Lepidodendon elegans, *Brongn.* —— gracile, *Lindl.*	= L. obovatum, *Sternb.*
Lepidophyllum lanceolatum, *Lindl.*	
Lepidostrobus variabilis, *Lindl.*	
Sternbergia approximata, *Brongn.*	
Sigillaria pachyderma? *Brongn.*	
Sphenophyllum erosum, *Lindl.*	
Trigonocarpon dubium (*Sternb.*).	
Finely striated stems = Diploxylon elegans?, *Corda.*	
Alethopteris lonchitica, *Brongn.*	
Neuropteris auriculata, *Brongn.*	
Pecopteris, sp.	
Sphenopteris latifolia, *Lindl.*	
Algæ—or rootlets.	

The above fossils are all found within six or eight inches of the coal. The fish, crustacean, and molluscan remains are intermixed with the plants. The animal remains occur rarely; but the plants are so numerous in some places as to quite blacken the shale. None of the species are in good preservation; and on this account some are only doubtfully determined. The most remarkable fossil of this group of species is that doubtfully referred to Algæ, which may possibly belong to an unknown form of rootlet, and which will be afterwards more fully referred to (p. 251).

The coal itself contains many large stems, flattened and coarsely

furrowed. Seaward, where it passes into a calcareous black-band ironstone, it contains the following fossils *:—

Leaia Leidyi, *Lea.*
Carbonia fabulina, *Jones & Kirkby.*
—— Rankiniana, *J. & K.*
—— secans, *J. & K.*
Spirorbis carbonarius, *Murch.*
Ganoid scales and fragments of fish-bones.
Stigmarian rootlets.

The fireclay under the coal contains many rootlets; and in the shale No. 33, overlying the lower coal and thin limestone, there occur rootlets which differ from the ordinary Stigmarian type by branching or forking nearly at right angles at intervals of a foot or so. With the rootlets are rare specimens of species of *Neuropteris, Pecopteris,* and *Cyclopteris,* along with an *Anthracomya.*

Towards the base of the shale No. 42 there is a thin band of reddle composed of the remains of the Entomostracan *Carbonia Rankiniana,* with a few stray Ganoid scales and small fish-spines.

From the thin parting of dark shale No. 45 (and partly imbedded in the upper surface of the calcareous sandstone beneath) we have procured the species enumerated below, most of which are (or were) comparatively common.

Acanthodus spines.
Ctenacanthus hybodoides, *Egerton.*
Ctenodus sp., operculum, ribs, sphenoid and other bones.
Diplodus gibbosus, *Ag.*
Megalichthys Hibberti, *Ag.*
Palæoniscus sp., scales and plates.
Coprolites.
Lepidodendron aculeatum, *Sternb.*

At various horizons of the red and grey shale No. 47 occur numerous casts of a small *Anthracomya,* possibly *A. modiolaris,* or near it; also stray specimens of small Ganoid scales and teeth, *Carbonia Rankiniana,* and species of *Lepidodendron* and *Calamites.*

Low down in this thick shale there is a zone of plant-remains. From it have been obtained:—

Ganoid scales.
Calamites Suckovii, *Brongn.*
Lepidodendron sp.
Lepidophyllum lanceolatum, *Lindl.*
Neuropteris auriculata, *Brongn.*
Neuropteris sp.
Trigonocarpon olivaeforme, *Lindl.*

It has already been mentioned that fragments of wood and spines of *Acanthodus* are found on the surface of the calcareous sandstone No. 48; and this is the only other bed, at Methil, in which we have observed fossils.

The fossils we have noticed are, with few exceptions, badly preserved, and not such as easily attract attention, though very abundant in places, and easily enough found when looked for. The beds con-

* This locality, which is the only one in the Coal-measures where we have found *Leaia* at all plentiful, is best got at during equinoctial spring tides; at other times the rock is rarely laid bare at dead low water.

taining them are all exposed between tide-marks, in the space included from a little west of Methil Harbour to the mouth of Muiredge Den.

We are much indebted to the assistance of Dr. H. Woodward, Mr. R. Howse, and Dr. Traquair, in determining the species.

Note on the Algæ or Rootlets occurring in Bed No. 28. (Pl. VI.).—These Algæ, or rootlets, are only found in about an inch or less of the shale overlying the upper thin coal, and some three inches or so above it. They are not seen where the other vegetable fossils are most numerous, which, as has been stated, is in the portion of the shale immediately over the coal. They are very delicate and membranous, showing no structure or surface-marking, except in the larger specimens, where is seen the remains of an internal filament or cord (figs. 1, 2, & 4), apparently indicating what was once the centre of a very succulent plant. The subrectangular mode of branching of many of the specimens is very peculiar, as is also the symmetry, often to be observed, of the branching on each side of a stem or main branch (figs. 8, 9, & 10). We have noticed nothing like fructification on any of the specimens; nor are we at all certain that any of our examples show the natural ending of the smaller branches. And we have certainly not seen what the main stems spring from.

These singular fossils, which have been rarely met with in Carboniferous strata, so far as our knowledge extends, might be taken for the remains of marine Algæ of the genus *Chondrus*, from their appearance; but as they can only be proved to be such by their organs of reproduction, and none of the latter have been met with, we can only adduce their external characters in favour of this view. From this evidence alone, however, M. Adolphe Brongniart * described and figured *Fucoides strictus* and *F. multifidus*, and Professor Schimper, Göppert, and Count De Saporta *Chondrus fruticulosus* †. M. Lesquereux has found *Fucoides cauda-galli* ‡ in ordinary Coal-measures (as we should expect from the presence of salt water in many of our deep mines where surface-water has been prevented from getting down into the workings); so there is really no great improbability of Fucoids being met with in such strata, as it is well known that the fauna there found has more of a marine than a freshwater *facies*. The analysis of the limestone previously given, showing the presence of salts of lime and magnesia in the waters from which it was deposited, also points to any thing but a freshwater origin.

The only fossils that we have been able to find at all resembling our specimens are some described and figured by M. Heer § in his description of the plant-remains brought by Professor Nordenskjöld from Bear Island, in the Arctic Ocean, which that author takes to be the roots of *Lepidodendron*. Certainly the larger Methil fossils

* Histoire des Végétaux fossiles, plate ii. fig. 4; plate v. figs. 9 and 10.

† Traité de Paléontologie Végétale, plate ii. fig. 5.

‡ "On *Fucoides* in the Coal-formations," Trans. Amer. Phil. Soc. Philad. vol. xiii. p. 313.

§ Fossile Flora der Bären-Insel (Stockholm, 1871), taf. xiii. figs. 1 and 2.

so much resemble the Bear-Island ones that, in all probability, whatever the latter are finally determined to be, ours must follow *.

What are the roots of *Lepidodendron* is at present doubtful. One of us has shown that in structure *Halonia* exactly resembles *Lepidodendron*, and was probably the root of the latter plant. Up to the present time, so far as our knowledge extends, no well-marked specimen of *Lepidodendron* with its roots attached to it has been discovered, although M. Heer may have seen such. M. Lesquereux, one of the most experienced living authorities, in his description of *Halonia tortuosa*, appears to have observed his specimen *in situ*, and saw that it had not been flattened, but was in its original shape, that its natural position was not vertical but horizontal or prostrate, and that it was a fragment of a plant growing and expanding its branches upon the ground †. This fact in some degree sustains the view that *Halonia* was the root or rhizoma of *Lepidodendron*, with which, as previously stated, it is identical in structure.

It may be remarked, in conclusion, that these red rocks of Fife are higher Coal-measures than any seen on the east side of England, so far at least as we have observed in Northumberland, Durham, Yorkshire, and Derbyshire. The high position and general character of the strata naturally suggest that they are the equivalents, either in full or in part, of the Upper Coal-measures of Lancashire and other western districts of England. In one particular, however, they differ from the upper series of western England, as there is nothing in the Fife beds like the *Spirorbis*-limestone, which, in one or more bands, is so characteristic a feature of the Upper Coal-measures of the west, in their range from the Forest of Wyre northwards into Dumfriesshire and Ayrshire; neither is the development of the series in Fife so great as on the west side of the country, 2000 feet and upwards being its thickness in Lancashire and other districts in the west compared with less than 1000 feet in Fife; so that while the Coal-measures of Fife are evidently more complete in the possession of an upper set of beds than elsewhere on the east side of the country, it is probable that the thick mass of Lower, Middle, and Upper Coal-measures of the west country may represent more thoroughly, and more nearly approach the close of, this great upper division of Carboniferous strata ‡.

* The Editor has very kindly drawn my attention to the close resemblance of some of our figures of this fossil to those given by D. Stur as representing the foliage of what he terms *Archæocalamites radiatus*, Brongn., in his "Culmflora des mähr.-schles. Dachschiefers," in the 8th vol. of the 'Abhandlungen' of the Austrian Geological Institution, as will be seen on comparing figs. 5, 6, and 8 of his pl. iv., with our figs. 2, 3, 6, 7, and 8.—J. W. K.

† "Observations on the Structure of Fossil Plants found in the Carboniferous Strata," part iii. p. 94, vol. for 1871; and 'Pennsylvania Second Geol. Survey,' p. 413.

‡ Originally the Coal-measures on the east side of England were probably as complete as those on the west; for their junction with the overlying Permian rocks is always unconformable, so that it is not possible to say what amount of higher measures have been denuded. The highest Coal-measures that we have seen on the east side appear to be the Rotherham Red Rock, in South Yorkshire. It is possible that still higher beds may come in as the measures dip beneath the Permian and Triassic strata of South Yorkshire and Lincolnshire, which may be some day proved as the search for coal is continued eastward.

Detailed Section of Strata seen on the Coast between the River Leven and East Wemyss.*

		ft.	in.
1.	Red and purplish sandstone, rather fine-grained, soft and false-bedded. (Seen opposite to Innerleven and westward towards Methil, but not wholly exposed.)	200	0
2.	Red marl, stained with yellow in places	12	0
3.	Fine-grained marly red sandstone, full of light-coloured, slightly calcareous concretions, the latter prevailing so much in some parts as to change the character of the rock, and passing into No. 4	12	0
4.	Red sandstone, fine-grained and false-bedded (forming the rock on which is built the east pier of Methil Harbour)	20	0
5.	A soft bed, said to lie in the fairway of the harbour, which we have not seen	10	0
6.	Red sandstone, blotched with yellow at the top, fine-grained, thick and cross-bedded. (The West Beacon rock.)	33	0
7.	Yellow and red sandstone, thin-bedded	3	0
8.	Red shale, sandy and soft	6	0
9.	Red sandstone, laminated	4	0
10.	Red marl, speckled with green	15	0
11.	Reddish purple sandstone	3	0
12.	Red shale. (Stigmarian rootlets.)	2	0
13.	Red sandstone	3	0
14.	Red, purple, and yellow shale, variegated	1	0
15.	Variegated sandstone, hard		8
16.	Red marl, blotched with green and yellow at the top, and very red in places below. (*Neuropteris* and *Lepidodendron.*)	8	0
17.	Brownish purple sandstone		8
18.	Red marl, full of small calcareous concretions	6	0
19.	Red shale with strong sandy bands	7	0
20.	Red shale with yellow streaks, laminated	3	0
21.	Purple red shale, firm, and with green spots	4	0
22.	Red marl or fireclay	15	0
23.	Purplish sandstone, spotted with green	1	0
24.	Purple and red marl, with whitish blotches (at top) and concretions of irregular shape. (Ferns.)	12	0
25.	Red stone, hard and flinty	1	6
26.	Red, pinkish, purple, and greenish shale and fireclay, with hard concretions. (Calamites, Stigmarian rootlets, &c.)	14	6
27.	Purple and greenish sandstone	8	0
28.	Purple, red, and greenish shale. (Plants, fish, and Crustacean remains.)	10	6
29.	Coarse coal		2
30.	Grey fireclay, with red spots. (Stigmarian rootlets.)	4	0
31.	Grey and purple shale, laminated	2	0
32.	Purple and grey limestone		6
33.	Grey and purple shale. (*Neuropteris*, Stigmarian rootlets, &c.)	2	0
34.	Argillaceous limestone		9
35.	Coarse coal		3
36.	Greenish grey fireclay. (Stigmarian rootlets.)	1	6
37.	Grey sandstone, stained with red at top, soft and shaly	3	6
	Carried forward	430	6

* Taken about midway between high- and low-water mark.

Detailed Section of Strata (continued).

		ft.	in.
	Brought forward	430	6
38.	Red, pinkish, and light grey shale. (Stigmarian rootlets and *Lepidodendron.*)	9	0
39.	Purple limestone, argillaceous and hard		6
40.	Light grey shale	1	0
41.	Argillaceous limestone		4
42.	Red shale	2	6
43.	Reddle or hæmatite. (Composed of Entomostraca.)		1
44.	Grey shale		8
45.	Dark sandy shale. (Fish-bed.)		1
46.	Reddish purple sandstone	1	0
47.	Red, grey, purple, and pink shales, strong and sandy in places, soft in others, well laminated, with large discoidal calcareous concretions, and one or more bands of argillaceous limestone. (*Anthracomya* and plant-remains.)	36	0
48.	Red and yellowish sandstone, calcareous and hard, of very irregular structure, with false-bedding and ripple-marks. (This bed stands out as a reef rather to the west of Muiredge Den, and again to the east of Buckhaven. Beds 7–48 are all seen between Methil Harbour and a little to the west of Muiredge Den.)	3	0
49.	Red marl, with light green spots above and many calcareous concretions below	15	0
50.	Yellow sandstone	6	0
51.	Red or purplish marl, or fireclay	4	0
52.	Faint-red or purplish sandstone* (with light-coloured bands in places, coarse and gritty below, and with quartz-pebbles)	12	0
53.	Shale, not clearly seen	2	0
54.	Yellow or whitish sandstone above, light red with yellow bands below	11	0
55.	Purple sandy shale, with an irregular band of ochre	1	6
56.	Purple and yellow fireclay, variegated	5	0
57.	Yellow and purple sandstone, massive; with 1 foot of white sandstone at base	9	0
58.	Red shale, with yellow ochreous spots. (Calamites.)	10	0
59.	Yellow, white, and red sandstone, with a foot of white sandstone at the base	9	0
60.	Red shaly fireclay, with a band of coarse ochre near the top		
61.	Yellow and red sandstone in thin irregular beds	3	0
62.	Red shale, coarse	2	0
63.	Red sandstone, with a white band at the base	4	0
64.	Red and yellow shaly fireclay, with white veins	7	0
65.	Light purple (variegated with yellow, red, and white) fireclay, which in places is very yellow and ochreous. (Stigmarian rootlets.)	7	0
66.	Red and white sandstone, hard at the top	3	0
67.	Red sandy shale	1	0
68.	Red fireclay, speckled with white, coarse and sandy in places	5	0
69.	Red calcareous sandstone, coarse grained, and with a white band at the base	3	0
	Carried forward	604	2

* An outcrop of this sandstone is seen in Muiredge Den, near the mouth.

Detailed Section of Strata (continued).

		ft.	in.
	Brought forward	604	2
70.	Reddish purple shale	2	6
71.	Red and white sandstone of irregular structure	1	6
72.	Whitish and red fireclay, variegated, with irregular intercalations of white sandstone	9	0
73.	Purple and yellow sandy shale, ochreous in places	1	6
74.	Intercalations of red shaly sandstone and sandy shale	3	0
75.	Dull red fireclay veined with white, coarse and sandy. (Beds 70–75 are all exposed in front of Buckhaven.)	6	0
76.	Red, light red, and purple sandstone, with whitish parts, softish, thick-bedded, and weathering irregularly; coarse, and with quartz pebbles at the base. (Forms the reef immediately to the east of Buckhaven Harbour.)	30	0
77.	Repeated alternations of red, purple, and yellow shale or fireclay, and red and white sandstone—cropping out chiefly within the harbour, and partly in the low cliffs to the west of it	46	0
78.	Bright red fine-grained sandstone, with yellow patches below	5	0
79.	Yellow and purple sandy fireclay	12	0
80.	Dark red and yellow sandstone, thin-bedded and irregular in structure	4	0
81.	Yellow and light purple shale, sandy	1	6
82.	Light purple and yellow fireclay	4	0
83.	Purplish and yellow sandstone, an irregular bed	1	6
84.	Dull red and light-purple fireclay	5	0
85.	An irregular bed of purple and yellow sandstone	3	0
86.	Sandy fireclay, light-coloured	2	0
87.	Whitish, light purple, yellow, and red fireclay, beautifully variegated, and with large sandy intercalations	30	0
88.	Red and yellow sandstone	6	0
89.	White and red fireclay above; yellow, red, and purple below; beautifully variegated	15	0
90.	Red sandstone. (Stigmarian rootlets.)	3	0
91.	Red shale. (Calamites.)	1	0
92.	Whitish fireclay and shale, variegated with yellow and purple. (Stigmarian rootlets.)	10	0
93.	Red sandstone, an irregular bed	1	0
94.	Red, purple, yellow, and white fireclay and shale, finely variegated, and laminated in places	15	0
95.	Purple and whitish sandstone	1	6
96.	Red, purple, yellow, and white fireclay and shale, variegated and spotted	10	0
97.	Purple and yellowish sandstone	8	0
98.	Purple shale, with yellow spots above, sandy, not all seen	5	0
99.	Red sandstone, laminated and shaly above, generally softish, but hard in some places, and coarse and gritty, with quartz and clay-pebbles in other places, and much false bedded. (Seen on the shore and in the cliffs from east of the Gas-works to the west of East Wemyss.)	100	0
		947	2

EXPLANATION OF PLATE VI.

This Plate illustrates the various forms of the Algæ or rootlets from Methil. The figures are all of natural size.

Discussion.

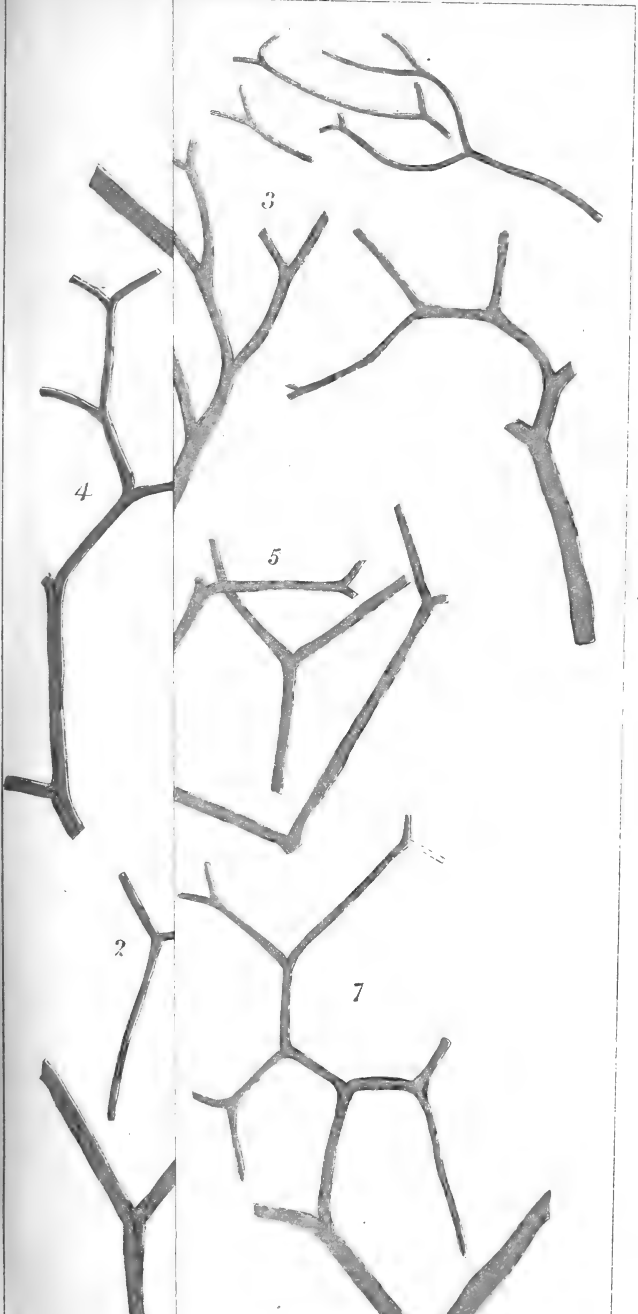
The President spoke of the value of the physical and palæontological information conveyed in this paper.

Mr. Tiddeman spoke of a section he had found along the Greta, near Ingleton, where some thin limestones occur at a considerable height above the true Coal-measures: over the latter were plant-bearing sandstones, shales, and clays; and apparently corresponding with them, on the other side of a synclinal, were beds of similar rocks, but with limestone interbedded. These were almost dolomitic. No organic remains had been found in them. It was, however, just possible that these limestones, being near the Great Craven Fault, might not be Upper Coal-measures but Yoredale-beds; but on the whole the probability lay the other way.

Mr. Cruttwell inquired the thickness of the limestone. In Australia there were limestones with *Productus reticulatus* under the productive Coal-measures.

Dr. Murie said he thought that rootlets of *Lepidodendron* had been found *in situ* in the north. He thought these beds could be traced westward to the other coal of Scotland.

The President remarked that it was singular how closely some of the Australian fossils corresponded with those of Britain.



J. W. K.

DANGERFIELD, LITH 22 BEDFORD S^T COVENT GARDEN

J. W. K.

PLANT REMAINS FROM METHIL.

Dangerfield, Lith 22 Bedford St Covent Garden

27. *On Fossil* Chilostomatous Bryozoa *from* Mount Gambier, South Australia. By Arthur Wm. Waters, Esq., F.G.S. (Read January 25, 1882.)

[Plates VII.–IX.]

The fossils which have been at my disposal for the present communication consist, first, of a pill-box full of Bryozoa, in the possession of the London Geological Society, which they kindly lent me for description; and, secondly, the collection made on the spot by Mr. Etheridge, Jun., who very obligingly lent it to me when I was preparing my paper on South-west Victorian Chilostomatous Bryozoa*. The material belonging to the London Geological Society was sent over by Mr. J. E. Tenison Woods, probably at the time he wrote his paper for the Geological Society "On some Tertiary Rocks in the Colony of South Australia," Quart. Journ. Geol. Soc. vol. xvi. 1860.

I have referred to many of the specimens from Mount Gambier in my paper just mentioned, and in the course of a few weeks hope to have a short communication ready on the Chilostomatous Bryozoa from Bairnsdale, Gippsland, Victoria, as I have at present in my hands for description Mr. J. R. Y. Goldstein's collection from that locality. On the completion of this series of papers on the Chilostomatous Bryozoa from the three localities, I propose to deal with the Cyclostomata from the three places in one paper, as the number of species of Cyclostomata is not very large. This series will refer to about two hundred species of Tertiary Bryozoa; and although those on the spot able to obtain large collections will no doubt find various points which I have only imperfectly appreciated, yet I hope that these contributions will make the study of these rich Bryozoa-beds easier for those who follow me; and the large number of species found in these two pill-boxes will give an idea of what a vast field yet remains unworked in Australian fossil Bryozoa.

The genus *Membranipora*, which was largely represented in the Cretaceous period in various modes of growth, will have to be divided; but for the present it will be best to wait until the group has been entirely worked up, both in the recent forms from the southern hemisphere and the fossils from various localities.

In giving the measurements of the aperture of fossils it will of course be understood that these cannot be made with the same exactitude as when we have to deal with recent species.

The number of species from Mount Gambier is 66 Chilostomata and a moderate number of Cyclostomata; and of these 66 Chilostomata

* Quart. Journ. Geol. Soc. vol. xxxvii. p. 309. I then stated my reasons for believing that the fossils were incorrectly labelled from Yarra-Yarra; and a friend writes to say that Mr. Watts is still alive and has told him that the material was given him by Mr. John Allen, who obtained it from Curdies Creek, about 30 miles east of Warrnamboul, and that no Tertiary beds are known on the Yarra-Yarra. This entirely confirms the ideas I expressed as to the probable origin of the material.

we have already found 26 in the material I described from South-west Victoria, 4 are known from Orakei Bay, New Zealand, and I have 21 from Bairnsdale; 30 are now living, of which 25 have been found in Australian waters. Two species are considered identical with species found in the European Chalk, 12 with European Miocene, and 12 with Pliocene.

Besides the forms I have found, Mr. Woods has described, from Mount Gambier, *Eschara cavernosa*, Woods, *E. Clarkei*, W., and *E. verrucosa*, Woods (non Peach).

In the following list of species, I refer to those mentioned in my previous paper under South-west Victoria, which we should perhaps now call Curdies Creek. I further indicate which are found in both the collection of the Geological Society and that of Mr. Etheridge, Jun., as by that means we may get some idea as to which are common species.

List of Species.

	Page.	Living.	Orakei Bay.	S.W. Victoria.	Bairnsdale.	Geol. Soc.	Eth. Junr.	Allies and Localities.
1. Catenicella ampla, *Waters*	259	...	...	*	...	*		
2. —— alata, *Thoms.*	260	*	...	*	...	*		
3. Cellaria fistulosa, *L.*	260	*	...	*	...	*	*	Mioc. and Plioc. of Europe.
4. —— malvinensis, *Busk*	260	*	...	*	*	*	*	
5. —— ovicellosa, *Stol.*	260	...	*	*	...	*		
6. —— perampla	260	...	...	...	...	*	*	
7. —— angustiloba, *Busk*	260	...	*	...	*	*	*	*Melicerita Charlesworthii & Membr. stenostoma*, Rss.
8. Canda fossilis, *Waters*	261	...	...	*	...	*		
9. Caberea Boryi, *Aud*	261	*	...	...	...	...	*	Pliocene of Europe.
10. —— grandis, *Hincks*	261	*	...	*	*	*		
11. Menipea innocua	261	...	...	...	...	*		
12. Membranipora confluens, *Rss.*	262	*	...	*	...	*	*	Cretac. Pliocene of Europe.
13. —— ovalis, *d'Orb.*	262	...	...	...	...	*		
14. —— macrostoma, *Rss.*	262	...	*	*	*	*	...	Miocene of Europe.
15. —— tripunctata	262	...	...	...	...	*		
16. —— radicifera, *Hincks*	262	*	...	...	...	*	*	
17. —— dentata, *d'Orb.*	263	...	...	...	...	*	*	Cretac. Pliocene of Europe.
18. —— cylindriformis, *Waters*	263	...	...	*	*	*	*	
19. —— articulata	264	...	...	...	...	*		
20. —— perversa	264	...	...	...	...	*		
21. —— sp.	264	...	...	...	...	*		
22. Micropora hippocrepis, *Goldf.*	264	*	...	...	...	*	...	Chalk, Europe; Miocene and Pliocene of Europe.
23. Steganoporella patula, *Waters.*	265	...	...	*	...	*		
24. —— magnilabris, *Busk*	265	*	...	...	*	*	...	Miocene of Europe.
25. Cribrilina radiata, *Moll*	265	*	...	...	...	*	...	Eoc., Mioc., Plioc., Post Pl.
26. Mucronella microstoma, *Norm.*	265	*	...	...	...	*		
27. —— coccinea, *Johnst.*	266	*	...	...	...	...	*	Mioc. and Plioc. of Europe.
28. —— mucronata, *Smitt*	266	*	...	*	*	*	*	
29. —— duplicata, *Waters*	266	...	...	*	...	*		
30. Microporella ciliata, *Pall*	266	*	...	...	...	*	*	Pliocene of Europe.

List of Species (continued).

	Page.	Living.	Orakei Bay.	S.W. Victoria.	Bairnsdale.	Geol. Soc.	Eth. Junr.	Allies and Localities.
31. Microporella violacea, v. fissa	267	*	...	*	...	*		
32. —— ferrea, var. perforata ...	267	...	...	...	...	*	*	
33. —— elevata, *Woods*	267	...	...	*	...	*	*	
34. —— yarraensis, *Waters*.........	267	*	...	*	*	*	*	
35. —— macropora, *Stol.*	267	...	...	...	...	*	...	Miocene of Europe. *Anarthropora monodon, &c.*
36. —— introversa	268	...	...	...	...	*	*	
37. Porina clypeata, *Waters*	268	...	...	*	...	*	*	
38. —— coronata, *Rss.*	268	*	*	*	*	*	*	Miocene, Europe; Eocene, New Zealand.
39. —— larvalis, *McG.*	269	*	...	...	*	*	*	
40. Lepralia spatulata, *Waters* ...	269	...	...	*	...	...	*	
41. —— foliacea, *Ell. & Sol.*	269	*	...	...	*	*	...	Pliocene of Europe.
42. —— edax, *Busk*.................	270	*	...	...	...	...	*	Crag; Miocene.
43. —— burlingtoniensis	270	...	...	...	*	*	*	
44. Monoporella crassicaulis	270	...	...	...	...	...	*	
45. —— crassatina	270	...	...	...	...	*	*	
46. —— hebetata....................	271	...	...	...	...	*	*	
47. —— oblonga	271	...	...	...	...	*		
48. Porella concinna, *Busk*	271	*	...	...	...	...	*	
49. Smittia Tatei, *T. Woods*.........	271	...	...	*	*	*	*	
50. —— reticulata, *McG*.....	272	*	...	...	*	*	*	Pliocene of Europe.
51. —— trispinosa, *Johnst.*	272	*	...	...	...	*		
52. —— seriata, *Rss.*	272	...	...	...	...	*	*	Miocene of Europe.
53. —— biincisa	272	...	...	...	...	*		
54. Schizoporella Cecilii, *Aud.* ...	272	*	...	...	...	*		
55. —— auriculata, *Hass*............	273	*	...	...	*	*	*	Pliocene of Europe.
56. —— tenella, *Rss.*	273	*	...	...	...	...	*	Miocene of Europe.
57. —— cornuta, *Gabb & H.*	273	...	...	...	...	*	...	Miocene, U. S.
58. —— conservata, *Waters*	273	...	...	*	...	*		
59. —— bombycina..................	274	...	...	...	*	*	*	
60. —— marginopora, *Rss.*	274	...	...	...	...	*	...	Cretaceous, U.S.; Miocene of Europe.
61. —— acuminata, *Hincks*	274	*	...	...	*	*		
62. —— filiformis	274	...	...	...	...	*	*	
63. Retepora marsupiata, *Sm*......	275	*	...	*	*	*	*	Florida.
64. —— rimata, *Waters*	275	...	...	*	*	*	*	
65. Cellepora yarraensis, *Waters*..	275	...	...	*	*	...	*	
66. —— fossa, *Haswell*	275	*	...	*	...	*	*	
67. —— scabra, *Fabr.*	275	...	...	...	...	*		
68. Lunulites cancellatus, *Busk*....	275	*	...	*	*	*		

1. Catenicella ampla, Waters.

"Bryozoa from S. W. Victoria," Quart. Journ. Geol. Soc. vol. xxxvii. 1881, p. 317, pl. xvi. figs. 46, 50.

The specimen from Mount Gambier is very badly preserved; but the dorsal surface seems sufficiently characteristic to leave no doubt as to the identity of this with the one described as *C. ampla.*

2. Catenicella alata, W. Thoms.

Catenicella alata, W. Thoms., "On new Genera and Species of Polyzoa from Coll. of Prof. Harvey," p. 80, pl. vi. fig. 4 (Zool. Bot. Assoc. Dublin, 1859, vol. i.).

Catenicella alata, Waters, *loc. cit.* p. 317, pl. xvi. figs. 47, 49, 58.

The Mount-Gambier specimens are very imperfectly preserved.

3. Cellaria fistulosa, L.

Loc. Living: widely distributed. Fossil: S. W. Victoria (A.W.W.).

4. Cellaria malvinensis, Busk.

Loc. Living: Falkland Islands. Fossil: S. W. Victoria (A.W.W.); Bairnsdale (A.W.W.).

5. Cellaria ovicellosa, Stol.

Salicornaria ovicellosa, Stol. Foss. Bry. Orak. p. 151, pl. xx. figs. 9, 10.

Cellaria ovicellosa, Waters, *loc. cit.* p. 321, pl. xiv. figs. 4, 5, 6; pl. xvii. fig. 62.

Oral aperture 0·08–0·09 millim. wide.

Loc. Fossil: Orakei Bay; S. W. Victoria (A.W.W.)

6. Cellaria perampla, sp. nov.

Zoarium small, cylindrical, with 4-6 zoœcia in a series. Zoœcia hexagonal, contracted below, bounded by a double rim scarcely raised; surface almost flat, raised round the aperture. Oral aperture large, with two teeth above and two below, about 0·18 millim. wide.

The zoœcia and aperture are larger than in any species with which I am acquainted: and I find that the size of the aperture is of considerable value in the determination of the *Cellariæ*. The oral aperture of *C. malvinensis* is about 0·17 millim.; of *C. gracilis*, *sinuosa* (off French coast), *fistulosa* (Mediterranean, British, and fossil), about 0·14 millim.; of *C. crassa* of the Crag (see Crag Polyz. fig. 4), about 0·13 millim.; of *C. angustiloba* and *Charlesworthii*, 0·11–0·13 millim.; *C. Johnsoni* (from various localities), about 0·09 millim.; of *C. ovicellosa*, 0·08 millim.; and of *C. tenuirostris* (from Tasmania), 0·13 millim.

7. Cellaria angustiloba, Busk. Plate IX. figs. 28, 29, 30.

Melicerita angustiloba, Busk, Quart. Journ. Geol. Soc. xvi. p. 261.

Melicerita angustiloba, Tenison Woods, Geol. Observations in S. Australia, p. 73, fig. 4, and Trans. Roy. Soc. Victoria, vol. vi. p. 5, fig. 8.

Melicerita angustiloba, Stoliczka, Foss. Bry. Orak. p. 155, pl. xx. figs. 15, 18.

Zoarium branched and probably sometimes jointed, branches compressed. Zoœcia hexagonal, with the zoœcial area slightly depressed, separated by a raised border; oral aperture arched above; lower lip raised, forming a plate in front; two teeth projecting into the aper-

ture from the distal edge. Avicularia not raised, in a triangular area, opening wide and short, rounded above and slightly rounded below, with a straight plate, with a sinus in the middle. Oral aperture 0·11–0·13 millim. wide. Ovarian opening?

I am only able to see the notch in the avicularium in one case, but think it is not accidental, but the usual structure. The lateral position of the avicularia is uncommon among the Membraniporidæ; and therefore a full description of the species is given.

The zoœcia are much larger than those in *Melicerita Charlesworthii*, M.-Ed., of the English Crag; but the avicularia show a relationship to those of *M. Charlesworthii*, in which, however, the opening is oval, approaching to circular, and not falciform as incorrectly described in the 'Crag Polyzoa.'

This would seem to be related to *Escharinella elegans*, d'Orb. pl. 683. fig. 12, *Membranipora stenostoma*, Rss. (non Busk), Öst.-ung. Mioc. pl. viii. fig. 14, some of the *Escharæ* described by Hagenow from the Maestricht chalk, and *Cellaria ornata*, d'Orb. Voy. dans l'Amér. mérid. pl. ii. fig. 10.

Loc. Mount Gambier (*Woods*); Orakei Bay (*Stol.*); Bairnsdale (*Goldst. coll.*); Muddy Creek beds, Hamilton, Victoria.

8. Canda fossilis, Waters.

Loc. cit. p. 322, pl. xvi. figs. 51, 52.

9. Caberea Boryi, Aud.

The "opercula" are preserved; and the fossil very closely resembles the recent *C. Boryi*; but at the same time the state of preservation does not permit of the determination with absolute certainty.

10. Caberea grandis, Hincks.

Caberea grandis, Hincks, "Contr. towards a Gen. History of the Mar. Polyz." p. 53, pl. iii. figs. 4, 4*a*, 4*b*, Ann. & Mag. Nat. Hist. July 1881.

Caberea rudis, Waters, *loc. cit.* p. 322, pl. xviii. fig. 86.

In one or two specimens the large erect avicularium is preserved.

Loc. Living: off Curtis Island (*H.*). Fossil: S. W. Victoria, Bairnsdale (*G. coll.*).

11. Menipea innocua, sp. nov. Plate IX. fig. 24.

Zoarium consisting of two rows of cells. Zoœcia elongate; aperture oval, occupying half the length of the cell, one spine on the outer margin above. Lateral avicularia small (?); on the front of the cell below the aperture a raised avicularium with mandible directed laterally. Dorsal surface showing the divisions of each zoœcium, but otherwise smooth and unarmed. Aperture 0·25–0·29 millim. long, 0·20–0·22 millim. wide.

The lateral avicularia are broken down; and therefore the shape cannot be determined; but apparently they were very small.

The front surface corresponds very much with *M. Jeffreysii*, Norm.; but the dorsal surface is different.

12. MEMBRANIPORA CONFLUENS, Rss. Plate IX. fig. 25*.

Escharina confluens, Rss. Verstein. der böhm. Kreid. p. 68, pl. xv. fig. 22.

Membranipora confluens, Rss. in Geinitz, 'Elbthalgeb.' ii. pl. xxiv. fig. 14; Novak "Bry. der böhm. Kreid." p. 11, pl. ii. figs. 17, 18, Denkschr. Ak. Wien, xxxvii.

Membranipora pedunculata, Hincks, "Contr. towards Hist. of Mar. Polyz." Ann. & Mag. Nat. Hist. s. 5, vol. vi. p. 377, pl. xvii. figs. 2, 2*a*.

Zoœcia subovate, produced and attenuated below. Aperture of area broad, round or somewhat elongate, frequently with the proximal edge nearly straight, margin broad, raised, sloping inwards. Ovicell small, globose, narrow. The aperture is about 0·22 millim. wide and of about the same length.

In the recent allies of this species, viz. *M. catenularia*, *Lacroixii*, *pilosa*, and *monostachys*, no ovicells are known, whereas in the fossil *Cellepora zetes*, d'Orb., *Flustrellaria fragilis*, d'Orb., *F. Franquana*, d'Orb., *Membranipora Franquana*, d'Orb., and *Membranipora elliptica*, Hag., there are very small or moderately small ovicells. In *Membranipora catenularia*, Manz., Castrocaro, there are ovicells; but that apparently should be called *M. confluens* and not *M. catenularia*. *Membranipora pedunculata*, Manz., has also ovicells, and would seem to be the present species.

Loc. Living: Ceylon (*H.*). Fossil: Cretaceous, Hundorf and Strehlen, Schillinge, near Bilin (Cenomanian); Pliocene, Castel-Arquato? S.W. Victoria.

13. MEMBRANIPORA OVALIS, d'Orb.?

Only a few cells are preserved, which have a very thick raised border. The aperture is very elongate, measuring 0·5 millim. long and only 0·19–0·25 millim. wide.

There are three distal rosette-plates, two near the front and one in the centre near the base.

14. MEMBRANIPORA MACROSTOMA, Rss. (in *Vinculariæ* forma).

Membranipora macrostoma, Rss., Waters, loc. cit. p. 323, pl. xiv. figs. 18, 19.

15. MEMBRANIPORA TRIPUNCTATA, sp. nov. Plate IX. fig. 35.

In *Vinculariæ* forma.

Zoœcia elongate, narrow, surrounded by a slightly raised rim; and the zoœcia are further divided by a narrow longitudinal band running between them. In the space below each zoœcium there are usually three pores. Aperture about 0·27 millim. long, 0·1 millim. wide.

16. MEMBRANIPORA RADICIFERA, Hincks. Plate IX. figs. 26, 27.

Membranipora radicifera, Hincks, "On a Collection of Polyzoa from Bass's Straits," p. 6, Lit. & Phil. Soc. Liverpool, April 18th, 1881,

* This figure is not successful, as the walls of the aperture (which slope inwards) are not very well shown.

and also "Contr. towards a Gen. Hist. of the Mar. Poly." p. 53, pl. ii. figs. 6, 6 *a*, 6 *b*, Ann. & Mag. Nat. Hist. s. 5, vol. viii. pl. ii.

In the fossil specimens the shape of the area is very irregular, often very elongate. The remains of the two spines are clearly to be seen, as also the basis of the forked spine and avicularium; and on the dorsal surface there are six depressions round each zoœcium. Oœcium globose. Surface apparently with elongate pores; but, from the state of fossilization, it is impossible to be sure about this point. On each of the six lateral walls a large, elongate, oval opening, representing the rosette-plate. Area of average cells 0·46 millim. long, 0·25 wide.

Loc. Living: Bass's Straits.

17. Membranipora dentata, d'Orb. Plate VIII. fig. 14.

Flustrellaria dentata, d'Orb. Pal. Franç. p. 525, pl. 725. figs. 17–21.

Membranipora annulus, Manzoni, Bry. foss. Ital. 4ta cont. p. 7, pl. i. fig. 9; Manzoni, I Briozoi di Castrocaro, p. 12, pl. i. fig. 9.

Zoarium incrusting. Zoœcia much raised at the distal end, with four large spines on the front of the cell and one or two large central ones at the extreme end at a rather lower level, often directed forwards. Aperture round or oval, nearly the length of the zoœcium. Ovicell large, the width of a zoœcium. The aperture is about 0·23 millim. wide.

In d'Orbigny's figure the spines are not so much forward; but otherwise there seems to be no difference. Specimens in my possession from the Pliocene of Rametto (Sicily) correspond in every particular with those from Mt. Gambier. I have had a Bryozoan colony sent me from New Zealand, marked *M. ciliata*, MacGillivray; and although MacGillivray's figure leaves determination very difficult, yet from the description I think my specimen is correctly determined. In this the distal end is not so much raised, and the central spine is not larger than the others, nor is the aperture quite so long; but I think it must be looked upon as an ally.

Loc. Cretaceous, Sainte Colombe (Manche), Senonian; Pliocene, Castelarquato, Parlascio, Orciano (*Manz.*); in the province of Reggio, Calabria, it occurs in the Helvetian, Zanclian, Astian, and Sicilian beds (*Seguenza*), Rametto (*A. W. W. coll.*).

18. Membranipora cylindriformis, Waters. Plate VIII. fig. 13.

Membranipora cylindriformis, Waters, loc. cit. p. 323, pl. xvii. fig. 74.

In the Mount Gambier and Bairnsdale specimens the cells are nearer together, so that there is frequently hardly any space between the areas. The small avicularium above the area is usually absent; and the suboral avicularium is frequently much raised at right angles to the axis of the zoarium, and is sometimes quite within the area; and we are then reminded of *Membranipora minax*. Aperture about 0·20 millim. wide.

Loc. S.W. Victoria and Bairnsdale.

19. Membranipora articulata, sp. nov. (in *Vinculariæ* forma). Plate VIII. figs. 15, 16.

Zoarium quadrilateral, erect. Zoœcia on all four faces, surrounded by an elongate hexagonal band; aperture long, rounded above, with straight sides and straight on the proximal end. A small, acute avicularium on each side, on a line with the top of the aperture. Aperture 0·37 millim. long, 0·14 millim. wide.

20. Membranipora perversa, sp. nov. Plate IX. fig. 32.

Zoarium in *Vinculariæ* forma. Zoœcia arranged quincuncially, divided by a raised border; the lower half of the area covered with a calcareous plate; aperture of area nearly the width of the zoœcium, nearly straight on the distal edge, rounded and contracted below. Aperture of area 0·23 millim. wide, 0·23 millim. long. A spine or avicularium just above the area on each side, and also one on each side above the ovicell. The ovicell is small, just above the area; but in the fossil all are broken down.

21. Membranipora, sp.

The cells in shape resemble those of *M. radicifera*, Hincks, but are much smaller, only measuring 0·22 millim. by 0·11 millim. Near the upper end there were several spines; and the broken-down walls of the ovicell show that it was rather large.

22. Micropora hippocrepis, Goldf.

Cellepora hippocrepis, Goldf. Petr. i. p. 26, Taf. ix. fig. 3. Reuss, Foss. Polyp. d. Wien. Tert. p. 94, pl. xi. fig. 14. Hag. Die Bry. der Maest. Kreidef. p. 91, pl. vi. fig. 17.

Membranipora bidens, Busk, Crag Polyz. p. 34, pl. ii. fig. 4; Busk, Fossil Polyz. near Mt. Gambier, Q. J. G. S. 1860, vol. xvi. p. 260.

Membranipora Rosselii, Manzoni, Bry. Foss. Ital. 4ta cont. p. 11, pl. iii. fig. 15.

Membranipora bidens, Reuss, Die foss. Bry. Öst.-Ung. p. 43, pl. x. figs. 10, 11. Manz. Bri. Castrocaro, p. 15, pl. ii. fig. 4. Waters; Bry. from Bruccoli, Trans. Manch. Geol. Soc. vol. xiv. p. 467. Seguenza, Le Form. Terz. nell Prov. di Reggio, pp. 80, 128, 198, 368; Accad. dei Lincei, ser. 3a, vol. vi. 1877 (pub. 1880).

Membranipora deplanata, Rss.

I formerly followed Mr. Busk and others in considering this the *M. bidens* of Hagenow; but that would seem to belong to another genus, as the aperture does not seem to have been the oral aperture, but was covered with a membrane in which was a smaller oral lid, resembling *Membranipora Rosselii*, Aud., and other *Membraniporæ*; whereas in the present species there seems reason for supposing that the aperture we see is the oral aperture. On this point the recent specimen I have from Capri does not throw any light, as all the organic parts, including the opercula, have disappeared. The zoœcia, in my Mediterranean specimen, are somewhat smaller (nearly a

third) than in the Australian fossil; but the size of the aperture is about the same, viz. about 0·07–0·08 millim. wide. Avicularia are only known from Maestricht; and possibly this species should be separated on that account.

Loc. Fossil: Cretaceous, Maestricht, Rügen; Miocene, Mödling (Vienna), Eisenstadt (Hungary), Niederlies (Moravia), Wildon (Styria), Val di Lonte (*A. W. W.*); Pliocene, Cor. Crag, Castrocaro (Italy), in the Helvetian, Tortonian, Zanclian, and Saharian of Reggio (Calabria, *Seguenza*); Bruccoli* (Sicily). Living: Capri, from the coral fisheries (*A. W. W. coll.*), 225 metres.

23. Steganoporella patula, Waters. Plate IX. fig. 31.

Micropora patula, Waters, loc. cit. p. 326.

It is difficult to see in the small fragments if this is a *Steganoporella* or a *Micropora*; but as it resembles in many respects *Steganoporella magnilabris*, it, in all probability, should be united to that genus. It differs from *S. magnilabris* in having the aperture close up to the distal end; and the aperture only occupies a quarter of the zoœcium, while in *S. magnilabris* it covers nearly one half. Aperture 0·26–0·31 millim. wide.

24. Steganoporella magnilabris, Busk.

Steganoporella elegans, Smitt, Floridan Bryozoa, p. 15, pl. iv. figs. 96–101.

Membranipora magnilabris, Busk, Mar. Polyz. p. 62, pl. lxv. fig. 4.

The Mount-Gambier specimen is only a fragment, and was only determined by means of comparison with the well-preserved specimens from Bairnsdale. The consideration of this species is deferred until I describe the Bairnsdale collection.

25. Cribrilina radiata, Moll (non d'Orb.).

Lepralia elegantissima, Seguenza, "Le form. terz. prov. di Reggio," Atti Reale Accad. dei Lincei, 1879–80, p. 83, pl. viii. fig. 11.

Cribrilina radiata, Hincks, Coll. of Polyz. from Bass's Straits, loc. cit. p. 10.

For other synonyms see Hincks, Brit. Mar. Polyz. p. 185. I, however, feel doubtful if the figure and description of *Reptescharella pygmæa*, d'Orbigny, are sufficient to justify our uniting it with *C. radiata.*

The specimens from Mt. Gambier are small, without avicularia or ovicells, with the pores surrounding the zoœcia well marked, as in *Lepralia Ungeri*, Reuss.

Loc. Living: European seas, Madeira, Florida, Bass's Straits (*Hincks*). Fossil: Eocene, Miocene, Pliocene, Postpliocene.

26. Mucronella.

This seems to be *M. microstoma*, Norm. (see Hincks, Brit. Mar.

* I gave the Arctic Seas as a locality in my Bruccoli paper; but this seems a mistake, and I think it has only been found living at Capri.

Polyz. p. 370, pl. xxxviii. figs. 3, 4); but as the oral aperture is obscured by the peristome, and there are no ovicells, I hesitate to call it *microstoma*.

27. Mucronella coccinea, Johnst.

Lepralia resupinata, Manzoni, I Briozoi del plioc. ant. di Castrocaro, p. 20, pl. ii. fig. 26; Waters, "Bry. from the Plioc. of Bruccoli," p. 474, fig. 7, Trans. Manch. Geol. Soc. vol. xiv. 1878.

In the specimen from Mt. Gambier the peristome is much raised, and the avicularia are placed much lower than is usual in recent specimens; and in this respect it resembles the figure given by Reuss (Die Bry. des öst-ung. Mioc. pl. vi. fig. 11). Perhaps the position of the avicularia entitle this and the fossil from Eisenstadt to rank as a variety.

I have *Mucronella coccinea* from Capri with the avicularia placed very low, as also fossil from the Pliocene of Sicily; and it is then easy to see that the worn specimens resemble *Lepralia resupinata*, Manz.

Loc. Living: European and Arctic seas. Fossil: Eocene, Miocene, and Pliocene of Europe.

28. Mucronella mucronata, Smitt.

Mucronella mucronata, Waters, loc. cit. p. 328, pl. xvii. fig. 66.

The specimen from Mt. Gambier is in the *Eschara* form. The mucro is small, and only to be seen on some zoœcia; but in the Bairnsdale specimen it more resembles the figures of the Floridan form; and, further, in the Bairnsdale specimens some of the avicularia are very large and are directed downwards, while a few point upwards. Smitt gives the avicularia pointing directly or diagonally upwards. There are also frequently two small openings, probably avicularian, just above the aperture, when the fossil much resembles *Reptescharipora rustica*, d'Orb. (Pal. Franç. pl. 720. figs. 9, 10), from the French Senonian.

Loc. Living: Florida. Fossil: S.W. Victoria and Bairnsdale (*Goldst. coll.*).

29. Mucronella duplicata, Waters (in *Vinculariæ* forma).

Mucronella duplicata, Waters, loc. cit. p. 328, pl. xvi. fig. 54.

In the specimen from Mt. Gambier the peristome is much larger and more raised than in my figure from South-west Victoria. The mandible of the avicularia has been broad, spatulate, directed inwards.

30. Microporella ciliata, Pall.

The avicularia are large and are placed high, so that the zoœcia in consequence are very broad. Oral aperture 0·13 millim. wide.

Loc. Living: Arctic seas, Britain, Mediterranean, Florida, New Zealand, Falkland Islands, Zanzibar, Aden, Arabian Sea, California, Port Fairy, and Warrnambool (Australia, *McG.*). Fossil: Pliocene, Crag, several localities in Italy, Calabria, and Sicily.

31. MICROPORELLA VIOLACEA, Johnst., var. FISSA, Hincks.

Microporella violacea, var. *fissa*, Waters, loc. cit. p. 329, pl. xv. fig. 26, pl. xvii. fig. 73.

Loc. Living: Indian Ocean (*H.*). Fossil: S.W. Victoria.

32. MICROPORELLA FERREA, Waters, var. PERFORATA. Plate VII. fig. 4.

I am in doubt as to the generic position of this species; but it seems clearly to be related to the fossil from South-west Victoria, as the mouth is similar in shape and about the same size, with the small avicularia in the mouth, and with similar large lateral zoœcial avicularia. The three or five large pores remind us of *Mucronella mucronata*; and *Eschara Liversidgei*, Woods, may belong to either of these species.

33. MICROPORELLA ELEVATA, T. Woods.

Eschara elevata, Woods, "On some Tert. Austr. Bry.," Trans. R. Soc. N. S. Wales, 1876, p. 2, fig. 10.

Microporella elevata, Waters, loc. cit. p. 330, pl. xvii. figs. 63, 64, pl. xviii. fig. 90.

Loc. Fossil: S.W. Victoria, Bairnsdale (*Goldst. coll.*).

34. MICROPORELLA YARRAENSIS, Waters.

Microporella yarraensis, Waters, loc. cit. p. 331, pl. xv. figs. 27, 28.

Eschara lichenoides, Busk (non M.-Ed.), Mar. Polyz. p. 90, pl. cvi. figs. 1–3.

In many specimens the large depressed area is absent; and in consequence of the state of fossilization I cannot always see any Microporellidan pore. There is often only one suboral avicularium.

I am unable to agree with Mr. Hincks in thinking that *Eschara lichenoides*, Busk, is identical with *E. mucronata*, MacGill., though the figure of the last is so unsatisfactory that I am by no means sure what it really represents, and it may be *M. coscinopora* or *violacea*.

The size of the aperture should of course be 0·06 millim. wide, not 0·6 millim. wide as previously printed.

Loc. Fossil: S.W. Victoria and Bairnsdale.

35. MICROPORELLA MACROPORA, Stol. Pl. VIII. fig. 18.

Lepralia macropora, Stoliczka, Olig. Bryoz. von Latdorf, p. 84, pl. ii. fig. 3; Sitzb. Ak. Wien, math.-naturwissensch. Cl. Bd. xlv. Abth. 1, 1862.

Zoarium in *Lepralia*-form. Zoœcia distinct, broad in the middle, tapering off to the distal end, moderately convex; surface perforated with rather large raised pores, arranged somewhat radially. On each side below the aperture an avicularium directed outwards; mandible probably pointing upwards; above the aperture a large spine or avicularium. Oral aperture rounded above, straight below, 0·13 millim. wide.

This differs from the Latdorf specimens in having two suboral avicularia, and should, perhaps, on that account be called var. *biarmata*. I am not able to see any median pore; but the character of the zoœcia with the two avicularia is very similar to that of *Microporella yarraensis*, Waters, *M. symmetrica*, W., *M. lichenoides*, Busk, *M. fuegiensis*, B., &c.; and, further, the Latdorf specimen shows denticulated pores, which is a common character in *Microporella*.

The median pore is often seen with difficulty; and as justifying my having placed the present form with *Microporella* I may mention that in *Tubucellaria cereoides* I have been unable to find any median pore in the calcareous wall; but in decalcified and stained preparations there is one pore about the middle of the cell, which is then readily distinguished from the other pores by being larger and the contents staining differently, showing that it is a *Porina*, a genus to which *Tubucellaria borealis* &c. have already been referred.

I consider *Microporella macropora* related to *Anarthropora monodon*, Busk, and *Escharipora stellata*, Smitt, and think that *Anarthropora monodon* and *Microporella macropora*, Stol., must probably be considered as synonyms.

Loc. Miocene: Latdorf.

36. Microporella introversa, sp. nov. Plate IX. figs. 33, 34.

Zoarium in *Lepralia*-form. Zoœcia indistinct, surface punctured, distal end somewhat raised; a large acute avicularium directed inwards at the side of the zoœcium and considerably below the aperture. Oral aperture rounded above, contracted below, with a straight proximal edge. The suboral pore is very indistinct and small, obovate. Oral aperture 0·2 millim. wide, 0·16 millim. long.

This would be *Diporula*, Hincks; but I have not found it advisable to separate it from *Microporella*. This species differs from *Microporella* (*Diporula*) *verrucosa*, Peach, in habit, and also in having the avicularium directed towards the oral aperture.

37. Porina clypeata, Waters.

Porina clypeata, Waters, loc. cit. p. 332, pl. xvii. fig. 67.
S.W. Victoria.

38. Porina coronata, Rss.

Porina coronata, Waters, loc. cit. p. 333; and to the synonyms there given must be added

Pustulipora ungulata, T. Woods, "Tert. Austr. Polyz.," Tr. R. Soc. New S. Wales, 1876, p. 150 (4).

This was common in the Mount Gambier beds, also from Bairnsdale (*Goldst. coll.*), and has been found in the Schnapper Point beds, Victoria.

39. Porina larvalis, MacGill. Plate VIII. fig. 19 *.

Lepralia larvalis, MacGillivray, Nat. Hist. of Vict. dec. iv. p. 30, pl. xxxvii. fig. 5.

Zoarium cylindrical, foliaceous, or incrusting. Zoœcia not very distinct, upper part raised; immediately below the aperture two very large pores; below these, somewhat to one side, an avicularium with acute or elongate mandible. Surface with denticulated pores. Dorsal (or basal) surface in incrusting form open. One or sometimes two spines on each side of the aperture. Aperture (peristomial) 0·16 to 0·18 millim. wide.

The incrusting form from Australia is one of the most beautiful Bryozoa, to which the figure of MacGillivray does not do justice. It has a clear glassy shell, with the front of the peristome much projecting, with a central rim running down the peristome; and from this central ridge two smaller ones are given off to surround the large pores.

The generic position of the above is a most difficult question. The two large suboral pores are clearly important structures; and as they open into the peristome I have placed it with the Porinidæ; for I think we shall probably find that the pore of the Porinidæ opens into the throat, while the pore of the Microporellidæ opens into the body of the zoœcium. As an example, the pore of *Porina coronata* opens into the peristome above the operculum, whereas in *Microporella ænigmatica* (Q. J. G. S. vol. xxxvii. pl. xv. fig. 30) it is in the centre of the front wall. On the other hand, the denticulated pores (as seen in the recent specimens) are a Microporellidan character.

If this is united to *Porina*, the definition of the genus must be somewhat extended; and the same change has been made with the Microporellidæ, which Mr. Hincks described as with " a semilunate or circular pore on the front wall," whereas I think we may say that in both families there may be more than one pore.

Loc. Living: Williamstown (Victoria, *McG.*); Bondi Bay, New South Wales (*A. W. W.*), and Semaphore, Adelaide (*A. W. W.*). Fossil: Bairnsdale.

I have also seen it in the British Museum among undescribed material from the southern hemisphere.

40. Lepralia spatulata, Waters.

Lepralia spatulata, Waters, loc. cit. p. 335, pl. xviii. fig. 87.

The large spatulate avicularia scattered between the zoœcia are sometimes nearly as long as a zoœcium.

41. Lepralia foliacea, Ell. & Sol. Plate VII. fig. 3.

For synonyms see Hincks, Brit. Mar. Polyz. p. 300.

The position of the avicularium seems to vary, from being entirely in the mouth, to being placed some little distance down at one side,

* I am sorry that the lithographer has been very unsucessful with this figure. The aperture should have been shown more regular and without the wide denticle figured.

as in the figure. An exactly similar variety to the one figured occurs from Bairnsdale, as well as varieties with the avicularium in the mouth and punctured all over the surface.

Loc. Living: Hebrides and southern European seas; Cape of Good Hope; Indian Ocean. Fossil: Italian and Sicilian Pliocene, Bairnsdale.

42. Lepralia edax, Busk.

Cellepora edax, Busk, Crag Polyz. p. 59, pl. ix. fig. 6, pl. xxii. fig. 3.

Lepralia edax, Hincks, Brit. Mar. Polyz. p. 311, pl. xxiv. figs. 7, 7*a*, 8; Smitt, Floridan Bryozoa, pt. ii. 63, pl. xi. figs. 220–223.

Cumulipora angulata, v. Münst., Reuss, Septarienthon, p. 63, pl. viii. fig. 12.

In the Mount-Gambier specimen the oral aperture is quite at the distal extremity of the zoœcium, and is rather larger than in the specimen figured by Mr. Busk in the 'Crag Polyzoa,' but smaller than in the recent specimen figured by Mr. Hincks.

In the Australian specimen there are neither zoœcial avicularia nor ovicells. The suboral avicularia are small. Oral aperture 0·12 millim. wide, 0·13 millim. long, proximal edge 0·8 millim. The fragment is but small; but the cells are apparently heaped together in the usual *Cellepora* fashion.

Loc. Living: Guernsey, Florida. Fossil: Söllingen (Oberoligocän); Crag.

43. Lepralia burlingtoniensis, sp. nov. (in *Vincularicæ* forma). Plate VII. fig. 6.

Zoarium erect, cylindrical. Zoœcia hexagonal, distinct, divided by broad raised hexagonal divisions which extend round the oral aperture. The surface of each zoœcium somewhat rounded, with few large pores. Oral aperture at the distal extremity 0·13 millim. wide.

Loc. Bairnsdale (*Goldstein coll.*).

44. Monoporella crassicaulis, sp. nov. Plate VIII. fig. 23.

Zoarium cylindrical, with six zoœcia in a complete series. Zoœcia smooth, indistinct. Oral aperture much depressed, horseshoe-shaped, slightly contracted towards the proximal edge, which is straight. On each side in the depression a small opening, which may have been avicularian. Two distal rosette-plates about the middle of the distal wall.

45. Monoporella crassatina, sp. nov. Plate VII. fig. 8.

Zoarium erect, in *Eschara*-form, with about eight cells in a complete series. Zoœcia ovate or elongate, distinct, raised; surface covered with large pores. Oral aperture large, rounded above, more or less straight below.

In one specimen, which I believe to be of this species, the cells are much longer and the mouth is much more square, as the corners at the base of the aperture are rounded off; and it then looks much

like *Lepralia Pallasiana.* The oral aperture is 0·18 to 0·22 millim. wide.

46. Monoporella hebetata, sp. nov. Plate VII. fig. 11.

Zoarium in *Lepralia*-form. Zoœcia small, broad, contracted towards the base; surface with few large pores (which may be denticulate). Two avicularia on a level with the oral aperture Oral aperture nearly semicircular, contracted below, proximal edge straight. The proximal edge of the aperture is about 0·12 millim. wide, while the widest part is 0·14 millim.

On the under surface there are projections, which in some cases are perforated; and perhaps it was attached by tubular radicles.

47. Monoporella oblonga, sp. nov. Plate VII. fig. 9.

Zoarium probably in *Hemeschara*-stadium. Zoœcia elongate, with nearly parallel sides, distinct, divided by a thin raised line; a little below the aperture on each side close to the border a small rounded avicularium directed outwards; oral aperture large, about the width of the zoœcium, rounded at the distal end, rather straight below, with the sides also straight, but with the corners rounded off. Oral aperture 0·31 millim. wide, 0·28 millim. long.

This may be related to *Lepralia rubens,* Stimpson.

48. Porella concinna, Busk.

Lepralia concinna, Busk, B. M. Cat. ii. p. 67, pl. xcix.

Porella concinna, Hincks, Brit. Mar. Polyz. p. 323, pl. xlvi.; Hincks, "Coll. of Polyz. from Bass's Straits," p. 16, Proc. Lit. & Phil. Soc. Liverpool, 1881.

Zoarium in *Eschara*-form. Zoœcia punctured over the entire surface. Oral aperture 0·14 millim. wide.

I have this species from Rapallo (Italy) also in *Eschara*-form.

Loc. Living: Northern seas, Mediterranean, Bass's Straits (*H.*). Fossil: Postpliocene.

49. Smittia Tatei, T. Woods. Plate VII. fig. 10; pl. VIII. fig. 21.

Eschara Tatei, T. Woods, "On some Tert. Austr. Polyz." Roy. Soc. N. S. Wales, 1876, p. 3, fig. xv.

Eschara porrecta, T. Woods, loc. cit. p. 1. figs. 2, 3.

Smittia Tatei, Waters, loc. cit. p. 337, pl. xvii. fig. 65.

This is a common but rather variable species. The zoaria are sometimes very small, with only a few zoœcia in a series; other specimens are foliaceous. The long acute avicularium is sometimes found in every zoœcium, while in other cases it is but seldom met with.

Eschara parallela, Reuss, from the Italian Miocene, much resembles this; but the suboral avicularium is absent.

Athough this is a common species, I have only seen a single ovicell, which is globose, not very much raised. This species would seem to be closely related to *S. Landsborovii.*

50. SMITTIA RETICULATA, MacGill.

See Hincks, Brit. Mar. Polyz. p. 346, pl. xlviii. figs. 1, 5.

Smittia reticulata, Hincks, On a Coll. of Polyzoa from Bass's Straits, p. 16, & Ann. Nat. Hist. Aug. 1881, p. 64.

Loc. Living: Northern Seas, Britain, Mediterranean, Falkland Islands, Australia. Fossil: Bairnsdale.

51. SMITTIA TRISPINOSA, Johnston. Plate VIII. fig. 20.

There is only a small fragment badly preserved; but the oral and lateral denticles are preserved, and there are one or two avicularia at the side of the mouth directed upwards.

52. SMITTIA SERIATA, Rss. Plate VIII. fig. 17.

Lepralia seriata, Rss. Die foss. Bryoz. des. öst.-ung. Miocäns, p. 32, pl. ii. fig. 12.

Zoarium in *Eschara*-form, branches 2–3 millim. wide. Zoœcia usually flat, separated by a wide slightly raised margin, oblong, arched above, sides parallel, four more or less regular rows of parallel pores, between which are rounded granulations; oral aperture horseshoe-shaped, rather contracted below, proximal edge straight, with a large rounded or angular denticle turned inwards, also a denticle on each side of the aperture. Oral aperture 0·14 millim. wide.

It is difficult to know where this should be generically placed; but as the peristomial characters in *Smittia* are very variable, we seem to be justified in placing it with *Smittia*, on account of the form of the denticles.

Loc. Miocene: Rauchstahlbrunngraben (Baden).

53. SMITTIA BIINCISA, sp. nov. Plate VII. fig. 1.

Zoarium orbicular, somewhat convex, with the zoœcia radiating from the centre. Zoœcia distinct, ovate, raised, with a prominent mucro or avicularium immediately below the oral aperture, and two much-raised tubular avicularia above the aperture. The area of the mucro is without pores; but below this there is an irregular double row of large pores; oral aperture rounded above, with a prominent expanded denticle in the aperture, giving the appearance of two distinct sinuses. Oral aperture 0·12 millim. wide. Distal rosette-plate near the base of the distal wall, very elongate. I am unable to see the shape of the true oral aperture, but think that the denticle (although placed higher than is usual in *Smittia*) indicates the generic affinity.

54. SCHIZOPORELLA CECILII, Aud.

Flustra Cecilii, Aud. Savigny, Egypte, p. 66, pl. viii. fig. 3.

Schizoporella Cecilii, Hincks, Brit. Mar. Polyz. p. 269, pl. xliii. fig. 6.

Lepralia Cecilii, MacGillivray, Zoology of Victoria, decade iv. p. 21, pl. xxxv. fig. 2.

Schizoporella Gandyi, Haswell, On some Polyzoa from the Queensland Coast, p. 40.

Oral aperture 0·13 millim. wide, 0·1 millim. long.

Loc. Living: Cornwall, Jersey, Guernsey, Mediterranean, Red Sea, Japan; Warrnambool, Victoria.

55. Schizoporella auriculata, Hass.

This occurs in the *Vincularia*- and *Lepralia*-form in Mount Gambier, and in the *Hemeschara*-form in Bairnsdale.

Loc. Pliocene: Bruccoli (Sicily), and in Saharian beds of Reggio (Calabria). Living: European and Australian seas.

56. Schizoporella tenella, Rss.

Cellepora tenella, Reuss, Die foss. Polyp. des Wiener Tert.

Reptoporina tenella, d'Orb. Pal. Franç. p. 442.

Lepralia tenella, Reuss, Die foss. Bry. des öst.-ung. Miocäns, p. 23, pl. vi. figs. 3–5.

The zoarium consists of zoœcia in a single layer forming a hollow cylinder about 2·5 millim. diameter (probably it has grown over the round stem of some seaweed). Zoœcia in irregular longitudinal rows, divided by a much-raised border; irregularly oblong with parallel sides or rhomboidal surface coarsely granulated and perforated, below the aperture a narrow acute avicularium directed downwards. Oral aperture rounded on the distal end, proximal with a large rounded sinus; in some cases the aperture is much contracted above the sinus; 1 millim. wide, 0·9 long. Sometimes the distal border extends as a bar above the middle of the aperture, so that the opening appears divided into two.

This much resembles *Lepralia subimmersa* and *anceps*, MacGillivray (Prodr. of Zool. p. 23, Decade iv.), but differs from the former in the shape and direction of the avicularium, and from *Smittia anceps* in having no denticle.

Loc. Miocene: various localities in Austria and Hungary.

57. Schizoporella cornuta, Gabb & Horn. Plate VII. fig. 5.

Reptescharellina cornuta, G. & H., "Fossil Polyz. of the Second. & Tert. Form. of N. Amer." p. 147, pl. xx. fig. 31, Journ. Ac. Nat. Sc. Philad. vol. v. pt. ii. 1862.

Zoœcia quadrangular, elongate, sides nearly parallel, surface coarsely punctate, a raised avicularium at each side of the oral aperture. Oral aperture rounded at the distal end, with a wide sinus at the proximal. Width 0·10 millim., length 0.11. Ovicell raised, globular, about the width of the zoœcium.

Loc. Miocene: Santa Barbara (Carolina), *G.* & *H.*

58. Schizoporella conservata, Waters. Plate VII. fig. 7.

Schizoporella conservata, Waters, loc. cit. p. 340, pl. xviii. fig. 81.

59. Schizoporella bombycina, sp. nov. Plate IX. fig. 36.

Zoarium in *Lepralia*-form, zoœcia subhexagonal to ovoid, surface with transverse lines. Ovicells globular, very small, not double the diameter of the oral aperture. Oral aperture formed at the distal end of a semicircle, 0·13 millim. in diameter, with a broad sinus at the proximal end. A raised triangular avicularium at one side a little below the mouth. This corresponds in many particulars with *Cellepora pumila* and *C. inornata*, Gabb and Horn, but the shape of the aperture is formed by two definite arcs, and the ovicells are not acuminate.

60. Schizoporella marginopora, Rss. Plate VII. fig. 2.

Cellepora marginopora, Rss. Foss. Polyp. Wien. Tert. p. 88, pl. x. fig. 23.

Reptescharellina prolifera, Gabb & Horn, Monogr. Foss. Polyz. of the Second. & Tert. Form. of N. America, p. 146, fig. 28.

Zoœcia oval or elongate, raised at the distal end; oral aperture rounded with a broad sinus below, surrounded by a raised border which encloses the two lateral avicularia at the sides of the aperture. There is a slight depression in the border just below the sinus; this is evidently the remains of an avicularium. Oral aperture 0·25 millim. wide, 0·23 millim. long.

Loc. Fossil: Cretaceous, Mullica Hill (N. J., United States); Miocene, Bischofswart.

61. Schizoporella acuminata, Hincks.

Schizoporella acuminata, Hincks, "Polyzoa from Bass's Straits," Ann. & Mag. Nat. Hist. ser. 5, vol. viii. 1881, p. 62, pl. ii. fig. 1; Hincks, "On a Collection of Polyz. from Bass's Straits," Proc. Lit. & Phil. Soc. Liverpool, 1881, p. 15.

Zoœcia distinct, raised, broadly ovate; surface granular and perforate, with a small avicularium on one side a little below the orifice; oral aperture rounded on the distal edge, straight below, with a distinct narrow sinus; ovicell small, broad, short, and but very little raised. Oral aperture 0·15 millim. wide, 0·1 millim. long.

The extremity of the fossil is not so acuminate as in Mr. Hincks's figure from Bass's Straits; but this is not a constant character, as some cells are acuminate while others are round, and I have specimens from Bairnsdale in which none of the cells are acuminate.

Loc. Living: Curtis Island, not deeper than 40 fathoms (*H.*). Fossil: Bairnsdale.

62. Schizoporella filiformis, sp. nov. (in *Vinculariæ* forma). Plate VII. fig. 12.

Zoarium erect, with four or five cells in a series. Zoœcia elongate, subhexagonal, ridge arched, distinct, divided by wide raised borders, which are arched above; surface finely punctured; oral aperture rounded at the distal extremity, with a wide sinus at the proximal.

This may possibly be *Vincularia areolata* of Hagenow, from the Maestricht beds.

63. Retepora marsupiata, Smitt.

Retepora marsupiata, Waters, loc. cit. p. 342, pl. xv. figs. 34, 35, 36, pl. xvii. figs. 59, 61, 76, 77.

Loc. Living: Florida, Teneriffe. Fossil: S. Barbara, Amer.; S.W. Victoria (*A. W. W.*), Bairnsdale (*Goldstein coll.*).

64. Retepora rimata, Waters.

Retepora rimata, Waters, loc. cit. p. 343, pl. xvi. figs. 48, 53.

This is common from Mount Gambier and from Bairnsdale.

65. Cellepora yarraensis, Waters.

Cellepora yarraensis, Waters, loc. cit. p. 343.

This also occurs from Bairnsdale; and as it is better preserved there I purpose figuring one of the specimens from that locality.

66. Cellepora fossa, Haswell.

Sphæropora fossa, Haswell, "On Polyz. from Queensland Coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. i. p. 42, pl. iii. figs. 5, 6.

Cellepora fossa, Waters, loc. cit. p. 343, pl. xviii. fig. 89.

Loc. Living: Holborn Island. Fossil: S.W. Victoria (*A. W. W.*).

67. Cellepora scabra, Fabr.

Both in the Mount-Gambier and Bairnsdale collection there is a small fragment of *Cellepora* with a rostral avicularium in front of the aperture, with the mandible pointing upwards. The aperture is nearly round, and the ovicells are very much flattened.

68. Lunulites cancellatus, Busk.

Lunulites cancellata, Busk, Cat. Mar. Polyz. p. 101, pl. cxiii. figs. 4–7; Waters, loc. cit. p. 344.

I have a specimen from Bairnsdale which is better preserved than those from Mount Gambier or the fossil from South-west Victoria. The aperture is surrounded by semiglobular avicularia with small semicircular mandibles at one side. In a specimen from off Raton, New Guinea, there are also larger spatulate avicularia at the side of the oral aperture; and then we see that it is related to *Lunulites* (*Conescharellina*) *conicus*, Hasw.=*Lunulites incisa*, Hincks.

Loc. Living: Philippine Islands and New Guinea, 7 fathoms, &c. Fossil: S.W. Victoria (*A. W. W.*), Bairnsdale (*Goldst. coll.*).

Besides those named, there are a few undetermined species. First there is a bead of *Catenicella*, which looks very much like *C. marginata*, Waters; then there is an incrusting colony in the *Lepralia*-form with wide distinct zoœcia, with perforated surface and rather wide aperture, of which the distal end is round and the proximal straight or somewhat lip-like, and much resembling *Mucronella variolosa* (see plate li. fig. 7, Hincks's Brit. Mar. Polyz.); but there

does not seem to be any denticle. Another incrusting species with cells more or less erect, as in *Cellepora*, and with a very large aperture (about 0·25 millim. wide), contracted in the middle and expanded below, as in *Lepralia lata*, may be new, as I have been unable to identify with it any described species. There are also some pieces of *Retepora*, which might be *R. robusta*, Hincks, or *R. porcellana*, MacG.

The specimen figured in Pl. VIII. fig. 22 is probably a *Smittia*. The distal ends of the zoœcia are very much raised, giving the colony the appearance of *Diastopora*.

EXPLANATION OF PLATES VII.–IX.

Plate VII.

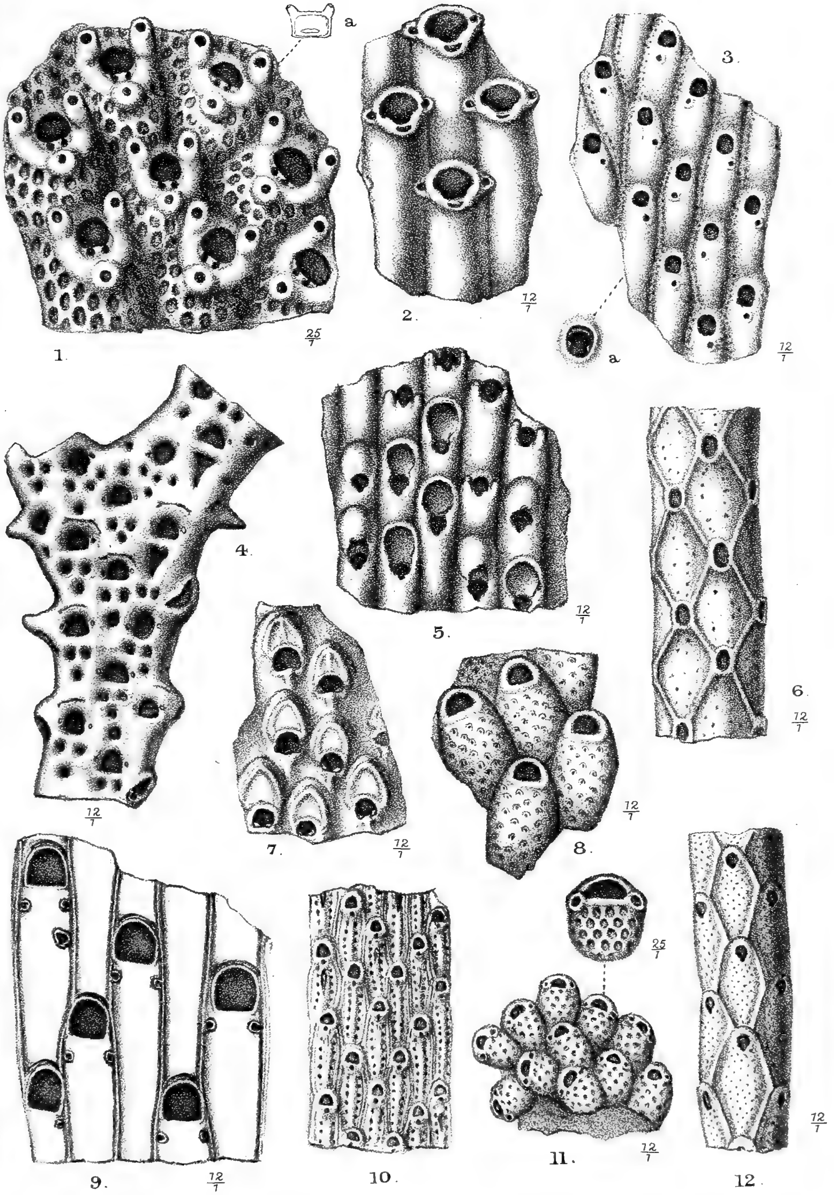
Fig.
1. *Smittia biincisa*, sp. nov., × 25: *a*, diagram of distal wall, showing rosette-plate, slightly magnified.
2. *Schizoporella marginopora*, Rss., × 12.
3. *Lepralia foliacea*, Ell. & Sol., × 12: *a*, enlarged aperture.
4. *Microporella ferrea*, var. *perforata*, × 12.
5. *Schizoporella cornuta*, Gabb & Horn, × 12.
6. *Lepralia burlingtoniensis*, sp. nov. × 12.
7. *Schizoporella conservata*, Waters, × 12.
8. *Monoporella crassatina*, sp. nov., × 12.
9. *Monoporella oblonga*, sp. nov., × 12.
10. *Smittia Tatei*, T. Woods, × 12.
11. *Monoporella hebetata*, sp. nov., × 12 and × 25.
12. *Schizoporella filiformis*, sp. nov., × 12.

Plate VIII.

13. *Membranipora cylindriformis*, Waters, × 12.
14. *Membranipora dentata*, sp. nov., × 25.
15. *Membranipora articulata*, sp. nov., × 25.
16. Ditto, × 12.
17. *Smittia seriata*, Rss., × 12: *a*, aperture more magnified.
18. *Microporella macropora*, Stol., × 12.
19. *Porina larvalis*, MacGill. × 12.
20. *Smittia trispinosa*, Johnst., × 12: *a*, enlarged aperture.
21. *Smittia Tatei*, T. Woods, × 25, figured from specimen from S.W. Victoria.
22. *Smittia* ? sp.
23. *Monoporella crassicaulis*, sp. nov., × 12: *a*, section showing position of rosette-plates.

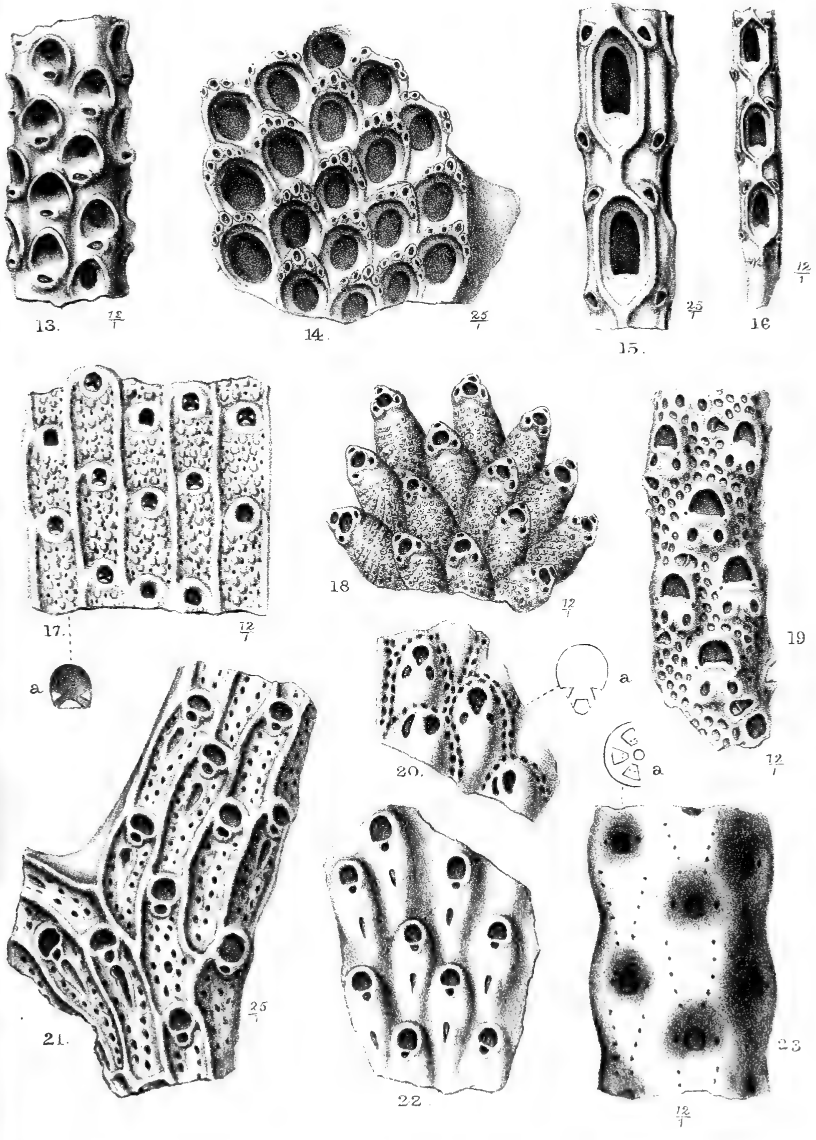
Plate IX.

24. *Menipea innocua*, sp. nov., × 12.
25. *Membranipora confluens*, sp. nov., × 25.
26. *Membranipora radicifera*, Hincks, × 25.
27. Diagrammatic view of sides of ditto, showing rosette-plate.
28. *Cellaria angustiloba*, Busk, × 25.
29. Avicularium of ditto, × 85.
30. Oral aperture of ditto, × 85.
31. *Steganoporella patula*, Waters, × 12.
32. *Membranipora perversa*, sp. nov., × 25.
33, 34. *Microporella introversa*, sp. nov., × 12 and × 25.
35. *Membranipora tripunctata*, sp. nov., × 25.
36. *Schizoporella bombycina*, sp. nov., × 12.



C. Berjeau lith. Mintern Bros. imp.

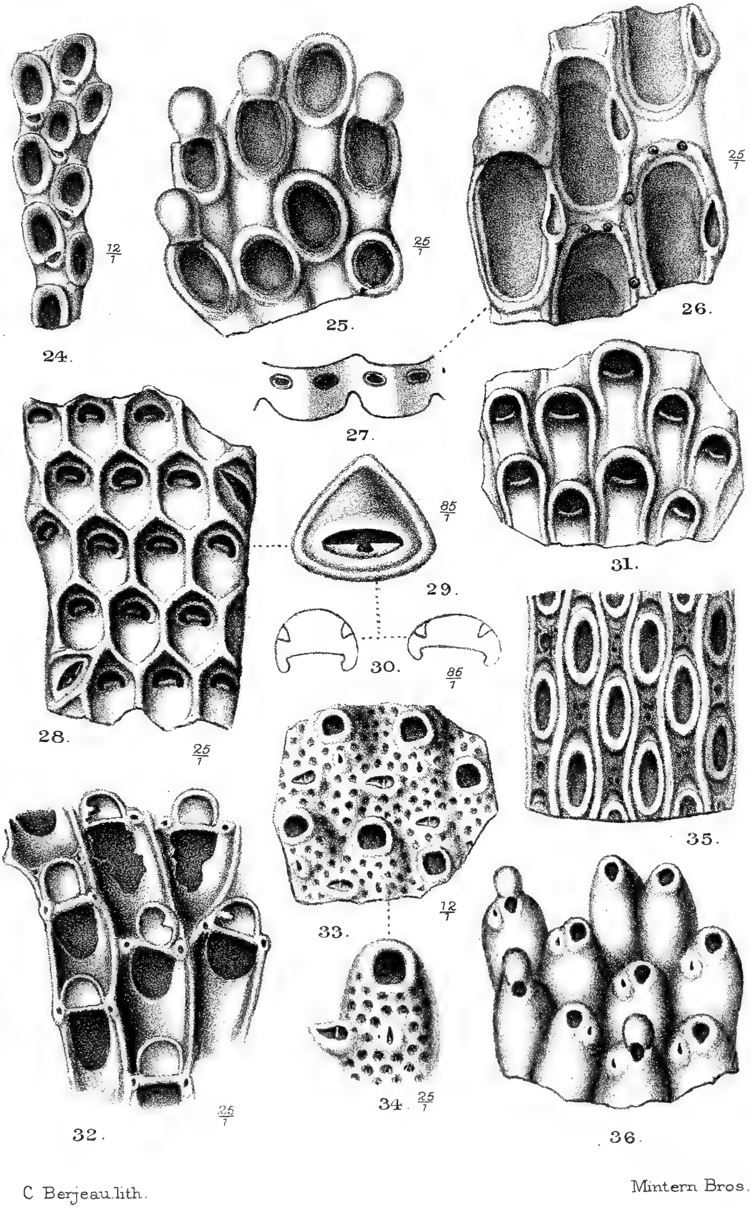
MOUNT-GAMBIER FOSSIL BRYOZOA.



C. Berjeau lith.

Mintern Bros imp.

MOUNT-GAMBIER FOSSIL BRYOZOA.



C. Berjeau lith.

Mintern Bros. lith.

MOUNT-GAMBIER FOSSIL BRYOZOA.

28. *The* Geology *of* Madeira. By J. Starkie Gardner, Esq., F.G.S. (Read March 8, 1882.)

The geology of Madeira has already formed the subject of three communications to this Society, and the present notes are therefore brief.

The island, it is well known, is almost wholly composed of basaltic rocks, which rise more or less precipitously from the sea and culminate in a central ridge of some 5000 or 6000 feet in height. Including the Desertas, which are separated by a narrow channel, only 400 feet in depth, its extreme length may be roughly stated at 50 miles, and its greatest breadth at 17 miles; yet so broken is the surface that some 250 miles must be traversed in order to become well acquainted with its varying scenery. The oldest of the basalts are considered to have been of submarine formation, and the only palæontological evidence as to their age consists of a small patch of coralline limestone included towards the north-west of the isle, and referred to the Upper Miocene; while a hitherto undescribed bed, with fossil plants, shows that volcanic activity was continued until the most recent period. There are, however, no traces of either hot springs, fumaroles, or sulphur deposits, though some of the lava-streams appear as unweathered as when newly formed; and immediately west of Funchal there are parasitic cones so little altered that it seems difficult to imagine them completely extinct. Madeira, since its discovery, has been profoundly quiescent; if any movement takes place, it is one of slow elevation.

The chief feature about the basalt is the enormous number of dykes which riddle them in every direction; and in this respect they are in striking contrast to the unbroken sheets which characterize Iceland and the Faroes. Every cliff and precipice shows sheet after sheet of lava, not continuous or parallel for long distances, but variable in thickness, interstratified with tuffs, scoriæ, and bright brick-coloured earths, and cut through in every direction by innumerable dykes. These dykes, weathered into mountain-tops of the most fantastic forms, give a grandeur and ruggedness to the scenery far beyond any thing I have met with in other basaltic districts, while the thorough immunity from glacial action has left the sides of the gorges and ravines in almost vertical precipices.

Occupying a nearly central position in the island is the Curral, a deep horseshoe-shaped valley, more than four miles in diameter and with its bed raised 2500 feet above the sea. It is almost encircled by precipitous walls, which tower 3000 feet above it, and embrace the loftiest peaks (Pico Ruivo 6050 feet, Sidrão 5500, the Torres 5980, &c.), from which radiate the principal mountain-chains in the island. The walls are breached to the south and form the outlet of a torrent, the Ribeira dos Soccorridos. This valley, at first narrow, widens into an ellipse, similar to, but in every respect less grand than,

the Curral, and continues thence as a narrow gorge to the sea. It is remarkable that this gigantic depression occupies an almost identical relative position in Madeira that the Peak occupies in Teneriffe, which would, moreover, if deprived of its central cone, strongly resemble it in size and in configuration.

Sir Charles Lyell, however, in the 'Elements of Geology,' 1865, expressed the opinion that the Curral was not an ancient crater, but a valley of erosion like the Little Curral or the neighbouring Serra d'Agua ; but as this view seems to have been omitted in later editions, it is possible that Sir Charles himself saw reason to change it. There can be no doubt, in fact, that it is actually a magnificent example of what Scrope has described as the basal wreck of a volcanic mountain blown into the air by some paroxysm of peculiar violence and persistence. Its almost perpendicular walls reveal sections of at least 3500 feet of stratified basalts and tuffs, through which enormous vertical trachytic dykes radiate as if from a common centre. The edge of the former crater, though fretted into mountain-peaks, preserves in many places the beds of scoriæ of the ancient cone, remains of which are seen sloping outwardly on all sides, at the usual angles of rest assumed by volcanic ash. The radiating dykes have been weathered on the eastern side into the inaccessible and fantastic summits of the Torres, while on the north and west are the more perfect and imposing masses of Ruivo and Canario. There is no other trace of any great crater throughout the island ; and it seems perfectly obvious that during the trachytic period, at least, this was the main vent whence the lavas and scoriæ were poured out. The two craters mentioned by Lyell, one at S. Antonio da Serra, towards the east end of the island, and the other to the west, on the edge of an elevated plateau, the Paül da Serra, are quite insignificant, and were probably only formed when volcanic activity was declining.

The Fossiliferous Limestone of Madeira.

It appears extremely probable that the limestone deposit to which I have already referred is the only one now exposed in the main island of Madeira ; for limestone is in request in building the great irrigation works so long in progress, yet it is now wholly imported from Porto Santo, where it is the fundamental formation of one of the smaller islets of the Porto Santo group. This deposit is situated on the left hand in ascending the gorge of São Vicenti, in a ravine known as the Achada do Furtado, 1350 feet above the sea, and consists of a tufaceous conglomerate with coralline limestone and other remains of a marine fauna. The upper part is crystalline and compact, with indistinct traces of Mollusca, though Bryozoa are sometimes beautifully weathered out, especially towards the top. Lower down it is less compact and contains shells, corals, and a large *Clypeaster*. Some 80 feet lower down is a kiln, and 25 feet below this again is a breccia of rounded boulders and fragments containing bivalves and spines of Echinodermata. The limestone is only partially exposed on

the sides of the ravine, and dips N.W. towards the sea at a high angle, so that it is difficult to estimate its thickness with any accuracy.

To the list of species published by Karl Meyer in Hartung's 'Geology of Madeira,' Mr. Yate Johnson has added *Pholadomya*, *Terebra*, and *Aturia zigzag*, from the supposed contemporaneous beds of Porto Santo.

The far more recent calcareous sand of Caniçal has been fully described by Lyell. All but two, however, of the Pulmonates which were then supposed to be extinct have since been found living; and the total number for the Madeiras has now risen to at least 165, for a single collection formed by Mr. Leacock contains this number.

The Fossiliferous Clays and Tuffs of Madeira.

The lignite bed of São Jorge, the only one in the island, is situated 1000 feet above the sea-level, in the depths of a wild gorge whose almost perpendicular sides of lava and scoriæ tower to a height of 2000 and 3000 feet. It is reached by ascending the rocky bed of a torrent, overhung by primeval laurel-woods which are carpeted with moss and a most luxuriant fern-growth. The spot has been visited by Lyell, Bunbury, Conybeare, and Hartung; but at some time previous to 1865 it was buried by a landslip and had not since been seen. In my visit during 1880 I was accompanied by Mr. Charles Cossart and a guide who was well acquainted with the spot and had formerly collected there; and with the assistance of our hammock-bearers we were able to clear the upper parts of the bed from tangle and débris. No lignite, however, was visible, although we apparently reached the basalt; and it is therefore probable that the thin bed of upper lignite in Hartung's section no longer exists. The beds appeared to be lenticular in section and of small extent, made up of compressed, light brown, shaly clays between layers of hard stone, and full of indistinct vegetable remains. In place of the lignite I saw 7 feet of blackish shales, with well-preserved twigs and branches, and resting on basalt.

The section, as given by Hartung, is:—

	ft.	in.
Tufaceous breccia, partly concealed, depth unknown.		
Hard clay	0	3
Tufaceous breccia with plants, passing right and left to basalt	3	0
Upper lignite	0	4
Underclay	10	0
Basalt	15	0
Lignite	—	?

No distinct remains of plants are now found, though they were formerly met with abundantly. Sir Charles Bunbury recognized *Woodwardia*, *Davallia*, *Nephrodium*, and other common Madeira ferns, and laid stress on the myrtle- and laurel-like character of the dicotyledons, which he considered all to belong to the existing flora of the island. Heer, however, in describing a collection made by Hartung, comprising 27 supposed species, referred many of them to

extinct forms, and several to plants not now indigenous to the island, a series of mistakes subsequently pointed out and rectified by Lowe in the 'Botany of Madeira.'

This appears to be the only known lignitic formation in the island, and is the only locality whence fossil plants have been obtained, except that discovered by Mr. Yate Johnson, and now to be described.

Facing the Ilha do Porto da Cruz, just east of and overshadowed by the vast Penha d'Aguia, whose sea-front presents a vertical cliff 1700 feet in height, lies a small promontory, whose height, though some 150 feet, is rendered utterly insignificant by the proximity of its gigantic neighbour. It is capped with a whitish or ashy-grey trachytic tuff, succeeded by layers of hard breccia and brittle, ferruginous, sandy tuff, about 15 beds of which recur interstratified together. In one of the lowest beds of the latter I obtained beautifully preserved leaves of two species of bramble, and both the leaves and flower-spikes of a Carex, while a little to the west a few silicified stems were imbedded. The leaf-bed I saw was extremely local, and may not have been exactly the same as that observed in the same locality by Mr. Yate Johnson some years since, who, indeed, found leaves on different horizons, some of which cannot be referred to *Rubus*. The whole formation rests upon a platform of highly vesicular basaltic lava, undermined into deep caverns by the sea. These tuffs and those overlying the formation are the only deposits of the kind in the island; they belong to the very latest of the igneous series of Madeira, and are probably Quaternary or Recent. Filling up a valley as they do, they must have been formed after the erosion of the whole series of basalts of the Penha d'Aguia into the present rectangular mass, 2000 feet high, by torrents whose powers seem utterly inadequate to have accomplished the work. Beds of lava and ash with an aggregate thickness of at least 2000 feet must have been ejected, at intervals which permitted the formation of considerable accumulations of vegetable soil, and again eroded through to the sea-level, between the close of the Miocene and the close of the volcanic period, if closed it be, of Madeira.

In conclusion I have to express my deep obligations to Mr. Leland C. Cossart for the hospitality which enabled me to explore so much of Madeira, and to Mr. Charles Cossart for the companionship which rendered our many fatiguing excursions a pleasure, as well as for the valuable assistance rendered me in collecting specimens and arranging for their safe arrival at their destination.

Discussion.

Mr. Etheridge said that the coralline limestone appeared to him to belong to the same as that of St. Thomas's, Barbadoes, and other West-Indian localities. He asked if the author had seen the *Pholadomya* mentioned; of that genus only one species now existed, namely *P. candida*. As for the leaves, a most able botanist was present. Much information upon the Miocene rocks may be obtained

from the memoirs on the Geology of Jamaica and Trinidad by Messrs. Sawkins and Wall.

Baron von Ettingshausen said that it was necessary to become familiar with plants that still existed in their various conditions of development, as affected by climate, soil, &c., before their variations could be understood. It was needful to compare a large number of specimens both of ancient and existing plants; and it must be remembered that variations existed in fossil plants, and that there were existing forms that reached backwards, and fossil forms that, as it were, extended forwards, so that great caution was needful.

Mr. Evans, after interpreting the remarks of Baron von Ettingshausen, who had spoken in German, said that these remarks showed the extreme need of caution in founding species and genera on isolated specimens of fossil plants. The variation in existing foliage was a strong warning against this.

Mr. Starkie Gardner said it was singular there should be only one calcareous formation in so large a division of the island. Lists of the fossils existed. He had called especial attention to the leaf-beds as a caution to palæobotanists; for he thought, as a rule, that plants could not be determined from mere leaves. He thought, however, that the value of plants had been too much overlooked. The Reading flora, recently exposed, corresponded remarkably with that of Greenland, which seemed to indicate that in the warmer mid-Eocene period the plants of more temperate regions migrated and went on living northward, whence, in the cooler Miocene times, they again descended.

29. *On the* Exploration *of* two Caves *in the Neighbourhood of* Tenby. By Ernest L. Jones, Esq. Communicated by Prof. W. Boyd Dawkins, F.R.S., F.G.S. (Read May 10, 1882.)

The object of the present paper is to give a short account of some facts recently brought to light during the exploration of two caves in the neighbourhood of Tenby.

The first of these, the cave of the Coygan, near Laugharne, was described by Dr. Hicks, who visited it some years ago; but, until recently, it had never been thoroughly explored, nor had it afforded any evidence of the presence of man. During the past summer it was examined by Mr. Laws, of Tenby, and myself with more success.

Before giving the results of our exploration, it may be advisable first of all to describe the fissure itself. The cave (fig. 1) is situated at the summit of an outlier of Mountain Limestone, which overlooks Caermarthen Bay, and forms a part of an ancient line of sea-cliffs. It is about 250 feet above the level of the sea. The entrance to the cave is below the level of the adjacent rocks, so that, in order to enter the cave, you have to descend a small pit or depression at the summit of the outlier. On entering, the passage is found to descend at an angle of about 30°, until a lofty cavern is reached at a distance of about 30 feet from the entrance. In the widest part the passage is about 30 feet across.

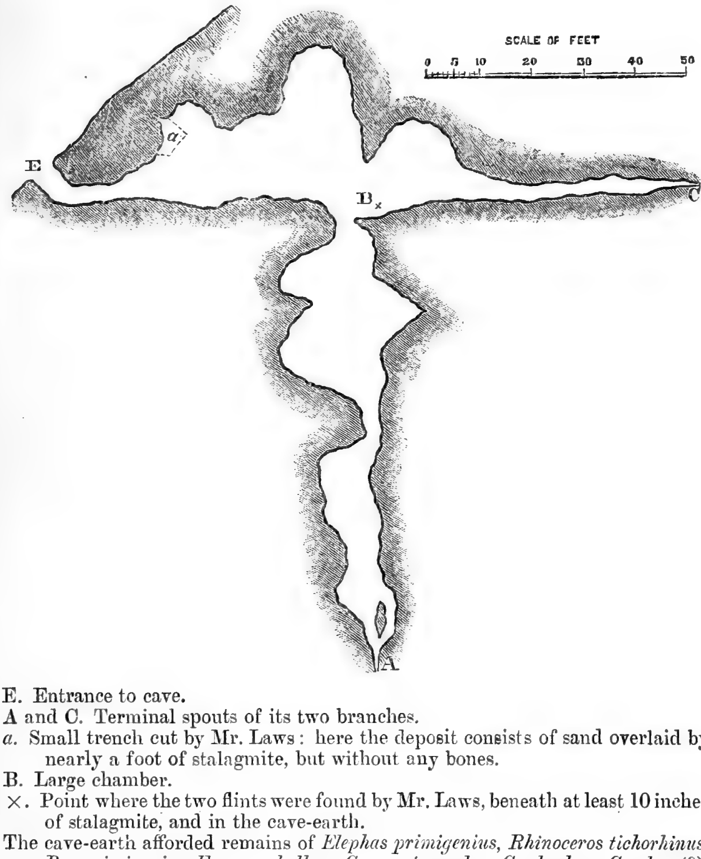
At this point the cave ramifies into two branches at right angles to one another; one of them enters for about 80 feet, running in a direction at right angles to the entrance-passage, and terminates in a "spout" (A) at about 130 feet from the mouth of the cave. The other branch, which is the prolongation of the entrance-passage, passes on for about 20 feet, forming a moderately large chamber (B); it then becomes gradually constricted, and terminates likewise in a spout (C) at a total distance of 117 feet from the entrance.

Before we began our excavations the cave-floor was covered with a deposit of stalagmite, which had only been broken through in one place; this stalagmite was moreover often concealed by fallen blocks and débris of recent accumulation. There was, however, no accumulation of black earth of neolithic date; and there were very few bones of recent animals above the stalagmite. The stalagmitic floor itself varied greatly in thickness, being sometimes quite 12 inches thick. After breaking through the stalagmite, which was very hard and crystalline, we came upon the breccia or cave-earth, in which we excavated a trench with very satisfactory results.

The most abundant remains were those of the Cave-Hyæna (*Hyæna spelæa*). The teeth and jaws of this creature were most abundant, the specimens belonging to individuals of all ages. The coprolites of the same animal were also found in incredible abundance, many of them occurring in flattened layers, as if they had been trampled

upon. A very large number of splinters and fragments of bone were scattered throughout the cave-earth, and all these bore the tooth-marks of the Hyæna.

Fig. 1.—*Reduced Ground-plan of Coygan Cave, near Laugharne, Caermarthen.*



E. Entrance to cave.
A and C. Terminal spouts of its two branches.
a. Small trench cut by Mr. Laws: here the deposit consists of sand overlaid by nearly a foot of stalagmite, but without any bones.
B. Large chamber.
×. Point where the two flints were found by Mr. Laws, beneath at least 10 inches of stalagmite, and in the cave-earth.
The cave-earth afforded remains of *Elephas primigenius, Rhinoceros tichorhinus, Bos primigenius, Equus caballus, Cervus tarandus, C. elaphus, C. alces* (?), *C. megaceros* (?), *C. capreolus, Hippopotamus* (?), *Hyæna spelæa, Felis spelæa, Ursus spelæus, Canis lupus, C. vulpes,* and palæolithic man.

The remains of the Horse (*Equus caballus*) were extremely plentiful, but they consisted almost entirely of teeth; and the few bones which we obtained were very much gnawed and decomposed.

The Mammoth (*Elephas primigenius*) was represented by the teeth of several individuals, varying considerably in age, and also by a few bones, which were, however, very much decomposed.

The teeth of the Woolly Rhinoceros (*Rh. tichorhinus*) were

tolerably plentiful; and we obtained a considerable number of bones of this creature.

The Hippopotamus (?) was represented by no very reliable specimens, and by no teeth whatever. This last fact, viz. the absence of the teeth, seems to throw additional doubt on the propriety of placing the Hippopotamus in the list of the fauna of the cave.

The Elk (*Cervus alces*?) was represented by a number of teeth, portions of the jaws and antlers, and a few bones.

The Red Deer and Roe Deer (*C. elaphus* and *C. capreolus*) were also found in the cave-earth.

The Reindeer (*C. tarandus*) was plentifully represented by teeth, bones, and portions of antlers.

The Cave-Bear (*Ursus spelæus*) was one of the most prominent Carnivores, being represented by several split and gnawed bones, and by several fine molars and canines of large size.

The Cave-Lion (*Felis spelæa*) was only represented by a portion of a fine canine.

A singular fact was the rarity of the remains of the genus *Bos*. Only three teeth have been found in the cave: these probably belong to *B. primigenius*.

In conclusion, the Wolf and Fox (*Canis lupus* and *C. vulpes*) must be added to this list.

The most important discovery, however, was the finding of *two flint flakes*, evidently chipped by man. These were taken out by Mr. Laws from beneath 10 inches of stalagmite, at the point × in fig. 1; they were *in situ*, embedded with the bones of the Mammoth and Rhinoceros, and were oxidized to a white colour. Besides these we found several bones which appear to have been cut by man, one appearing to have been intended for an awl. We have therefore the satisfaction of placing palæolithic man in the list of the fauna of the cave.

We may conclude that the cave was a hyæna-den. This fact is shown by the abundance of the teeth and coprolites of that creature, and by the fact that almost all the bones in the cave bore the tooth-marks of the same animal; while no water-worn pebbles or earth, other than that which appeared to have been derived from the decomposition of animal matter, were present. I have already referred to the distribution of the coprolites in flattened layers as if they had been trampled on.

We may conclude, then, that the whole of the deposit was formed by the dragging in and devouring piecemeal of body after body of the animals whose remains are here; and, looking at the enormous extent of the deposit, we are forced to conclude that many generations of Hyænas inhabited the cave. Perhaps it was occupied by these creatures at intervals; and between these periods it was in all probability frequented by the cave-men, who left here their rude implements of flint and bone.

Recently remains of the Mammoth have been brought to light in the submerged forest which skirts all the Pembrokeshire coast, and thus additional evidence is afforded by which to correlate the period

of the caves with that of the forest-bed. When the palæolithic men inhabited South Wales, the Bristol Channel was a large well-watered plain, with lakes which gigantic Hippopotami inhabited, some of it forest-land in which Elephants roamed, while over its plains swept herds of wild horses and perhaps oxen. The weaklings and stragglers of these readily fell a prey to the cowardly Hyænas, and were dragged piecemeal into such dens as the Coygan.

The second cave, the "Hoyle's Mouth," about two miles from Tenby, is situated in a spur of the "Ridgway," the synclinal axis which extends from Tenby to Pembroke. It was partially explored by the late Rector of Gumpreston, the Rev. G. Smith, who gave an account of his proceedings in a paper read before the British Association. The fissure had also been examined by others at various times.

It will perhaps be necessary to describe first of all the fissure itself (fig. 2). Entering by a wide and lofty embouchure (A) it soon becomes narrow, and, at a distance of about 60 feet, bends sharply. At a further distance of 60 feet a small chamber (C) is reached; the last and largest chamber (D) is about 30 feet further on, and from it the fissure is only practicable for a further distance of 10 feet in one direction, and with great difficulty for about the same distance in another direction (E).

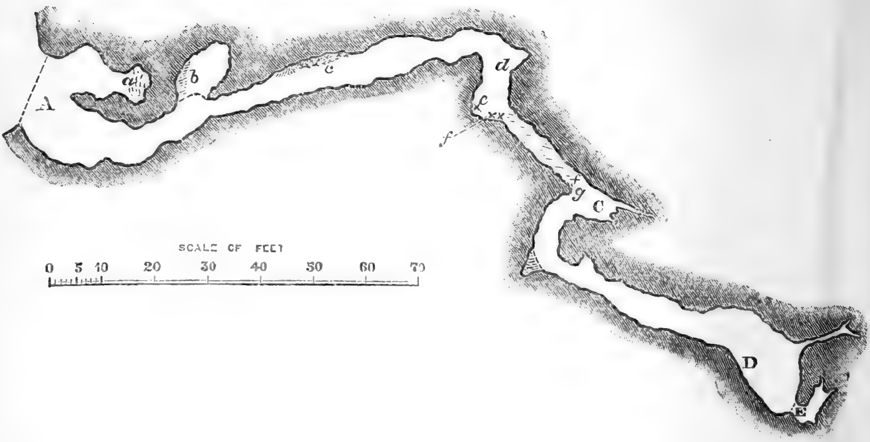
The remains in the collection of the late Rev. G. Smith are those of the Bear (*Ursus arctos*), Reindeer (*Cervus tarandus*), Irish Elk (*C. megaceros*?), and Red Deer (*C. elaphus*), with bones of recent animals, human bones, and flint flakes in considerable numbers.

These flint flakes were assigned by Mr. Smith and others to the palæolithic period; and some of the bones now in the Tenby Museum were described as those of the Cave-Bear (*U. spelæus*) and the Hyæna. The former, however, belong apparently to the Brown Bear (*U. arctos*); and the only evidence upon which the Hyæna is placed on the list is that afforded by two small bones, which have been gnawed, and which belong to the Brown Bear.

Three or four years ago I determined to examine the cave thoroughly, and with that object commenced operations in the inner chamber (D), in which the deposit had been much disturbed by previous explorers. Here, mixed up with the remains of recent animals, I found remains of the Brown Bear (*Ursus arctos*), the Reindeer (*Cervus tarandus*), the Ox (*Bos longifrons*), the Red Deer (*Cervus elaphus*), Wolf (*Canis lupus*) or the Dog (*C.*?), Fox (*C. vulpes*), one molar of a Horse (*Equus caballus*), with a small number of flint-chips.

As the deposit in this part of the cave had been disturbed, the chamber (C) was next examined, in which a considerable amount of recently accumulated débris concealed an unbroken floor of stalagmite. This floor was compact, crystalline, and upwards of 4 inches in thickness. In a hard breccia which underlaid it I found teeth and bones of the Brown Bear (*U. arctos*) and a single flint-flake. Remains of no other animals were found beneath the stalagmite; and, with the exception of two bones (before referred to), none showed the slightest trace of gnawing.

Fig. 2.—*Reduced Ground-plan of the Hoyle's Mouth Cave, near Tenby, Pembrokeshire.*



A. Mouth of the cave, in which most of the flints were found.
a. Many flint chips. *b.* Human remains.
C. Chamber containing remains of *Ursus arctos* in abundance, with one or two flints.
c. Remains of "hearth," charcoal &c., imbedded in stalagmite.
d. Sheep and Hog. *e.* Human bones.
f. Brown Bear. *g.* Flints.
D. Large chamber with many remains, including Brown Bear, Horse, Reindeer, Red Deer, and Roe Deer. Flint-flakes. It is in this chamber that remains of the Hyæna and Elk are said to have been found.
E. A small chamber, usually inaccessible. It did not afford any remains.

The shaded part represents undisturbed stalagmite of considerable thickness.

The outer part of the cave (A) was next examined, which had been previously explored by Mr. Smith; it was from this part of the cave, according to his own statement, that he obtained most of the flint-flakes in his collection. In this part, which is exposed to the daylight, and which had already been disturbed in most parts, I found remains of the Reindeer (*C. tarandus*), Hog (*S. scrofa*), Ox (*B. longifrons*), with bones of recent animals, human bones, and flint-flakes. These flints were almost all obtained from the left branch of the cave (*a*), and seemed clearly to indicate that they had been struck off by some one standing in the mouth of the cave. Among these chips are some of a peculiar green, pellucid, siliceous stone, quite unknown in the district; and it is a singular coincidence that in the Tenby Museum there lies a flake of the same material, obtained by Mr. Laws from the adjacent neolithic cave of Longbury.

In the Hoyle, about ten yards from the entrance, I found the

remains of a "hearth" (*c*), consisting of fragments of charcoal and burnt bones, imbedded in the stalagmite, which is here light in texture, and from 8 to 10 inches in thickness. A similar hearth was discovered in the above-mentioned neolithic cave of Longbury.

In looking at these remains we cannot fail to notice the marked contrast between this fauna on the one hand, and that found in the palæolithic caves of the district on the other.

The remains of the Hyæna have been alleged to be found in the cave; but I have never seen any remains whatever of that creature in any collection from the Hoyle; the two gnawed bones, already referred to, may not necessarily have been gnawed by the Hyæna. The remains of the Irish Elk are any thing but reliable. The Cave-Bear (*U. spelæus*) is absent, though the Brown Bear is abundant. The bones of this genus from the Hoyle and from the Coygan, when placed side by side, are to the most uninitiated decidedly those of different species. The Mammoth, Rhinoceros, and Hippopotamus are wanting.

While this striking contrast is observed between the remains found in the Hoyle and in the palæolithic caves of the district, an equally notable resemblance is observed between these remains and those afforded by the neolithic cave at Longbury. The similarity will be seen by reference to the list. The presence of a species is represented by a *.

Palæolithic forms.	Coygan.	Longbury.	Hoyle.
Elephas primigenius (Mammoth)	*		
Rhinoceros tichorhinus	*		
Hippopotamus amphibius	*?		
Hyæna spelæa	*		
Cervus alces ? (Elk)	*		
Cervus megaceros (Irish Elk)	?		?
Bos primigenius or *priscus*	*		
Felis spelæa (Cave-Lion)	*		
Ursus spelæus (Cave-Bear)	*		
Neolithic forms, and Palæolithic forms which have survived into the Neolithic period.			
Human bones	...	*	*
Flints &c.	*	*	*
Brown Bear (*U. arctos*)	...	*	*
Reindeer (*C. tarandus*)	*	...	*
Red Deer (*C. elaphus*)	*	*	*
Roe Deer (*C. capreolus*)	*	*	*
Hog (*Sus scrofa*)	...	*	*
Horse (*Equus caballus*)	*	* R	* R
Celtic Shorthorn (*B. longifrons*)	...	*	*
Dog or Wolf	*	*	*
Marine shells used for food	...	*	*

The presence of marine shells used for food, and of split and broken bones of animals, the existence of the "hearth," and the

manner of distribution of the flints in the mouth of the cave, show that the cave was used as a place of habitation. The distribution of the human bones, which were few in number, but well preserved, leads me (and led Mr. Smith) to infer that the cave had been used as a place of sepulture.

From these considerations, the remains in the Hoyle's Mouth must evidently be assigned, not to the palæolithic, but to the neolithic period.

Discussion.

Prof. Boyd Dawkins had examined the caves in question, and quite agreed with the author in his views concerning the Coygan cave. He was not so sure that some of the deposits in the Hoyle's Mouth are not palæolithic. He thought the caves ought to be called tunnel-caves, and not fissures. The mammoth remains of the Bristol Channel do not occur in the submarine forest, but in an underlying gravel. He did not consider the submarine forest as of Pleistocene, but of Neolithic age.

Dr. Hicks said though his friend Mr. Allen and himself were the first to explore the Coygan cave, he had not had the opportunity of making a complete investigation. He agreed with the author as to its being a Hyæna-den, and he had described it as such in his paper in 1867. He regretted that the worked flints were not exhibited to the Society, but was much pleased to find that they had been discovered, and that some fresh additions had been made to the list of animal remains found in the caverns.

30. *On some* Nodular Felsites *in the* Bala Group *of* North Wales.

By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S., Fellow of St. John's College, Cambridge. (Read April 5, 1882.)

[Plate X.]

The great group of felsites associated contemporaneously with sedimentary deposits of Bala age has been admirably described by Sir A. Ramsay in the Memoirs of the Geological Survey*, and its extent is indicated on their maps †. Some peculiar structures exhibited here and there in these ancient lava-flows have, I believe, remained hitherto undescribed, except by an incidental notice in that volume (pp. 93, 94), and in the Catalogue of Rock-specimens in the Jermyn-Street Museum. During the last two years I have devoted some time to the study of their microscopic structure, the results of which are perhaps of sufficient interest to be laid before the Society.

The lavas of this northern border of Wales, from the peak of Snowdon to the valley of the Conway, are, so far as I know them, generally compact, with a more or less conchoidal fracture, exhibiting sometimes a distinctly fluidal structure, and of a pale grey colour inclining to green ‡. Small scattered felspar crystals are not uncommon, and even minute grains of quartz; but, as a rule, these lavas are by no means distinctly porphyritic. Their general character, together with the special structures which I propose to describe, is well exhibited in more than one locality in the neighbourhood of Bettws-y-Coed. The highroad from the latter place to Pentre Voelas, on approaching the deep glen in which the falls of the Conway are concealed, runs at a considerable distance above the river on the right bank of the valley. Close to a little public house called the Conway Falls Inn we find the following section. The rock on either side of the house is a compact felsite. This continues for some distance as we ascend the road, and then becomes pretty distinctly cleaved, showing here and there a rather flattened nodule or spheroid about ½ inch in diameter, the interior of which is often hollow. To this succeeds a peculiar rock, which at the first glance might easily be taken for a true schist, cropping out so as to form a little crag or reef on the left hand-side of the road. It consists of wavy laminæ of a whitish material (apparently minute quartz and

* The Geology of North Wales (Memoirs, vol. iii.).

† They are a little below the horizon of the Bala limestone. For stratigraphical details I refer the reader to the excellent description in the memoir, ch. xiv.

‡ Several of the Snowdonian felsites with the associated ash-beds are carefully described by the late Mr. Ward in his paper "On the Microscopic Structure of Ancient and Modern Volcanic Rocks" (Quart. Journ. Geol. Soc. vol. xxxi. p. 401). I venture, however, to think that prolonged study would have enabled him to speak more confidently as to the distinction between the lava-flows and the finer ash-beds. Mr. Rutley also has recently described and figured some peculiar varieties from the Snowdon district (Quart. Journ. Geol. Soc. vol. xxxvii. p. 403).

felspathic constituents) and of films of a glistening pale green mineral, together with 'eyes' of quartz, and seemingly vesicles, about as big as a pea (but flattened), sometimes merely lined, sometimes nearly filled with a ferruginous mineral, which is often associated with quartz. This rock quickly passes into a less fissile and much more coarsely spheroidal rock, its nodules being often as large as a pigeon's or bantam's egg, ovoid in form and compressed-looking, round which the cleavage-planes are bent. A band about a couple of yards wide, almost free from "nodules," succeeds; and then comes another band like the former, the upper part of which is crowded with nodules (some attaining 5 inches in longest diameter). These weather out from the matrix so as to give the rock the aspect of a coarse conglomerate. For a short distance beyond this, the rock (so far as I followed it up the hill-side) is not exposed. Then succeed some rather compact dark-coloured rocks (cleaved) of ashy aspect and evidently sedimentary origin.

Before proceeding to describe the microscopic structure of the above rocks it may be well to notice briefly two or three other sections. By the wicket-gate leading down to the Conway Falls from the road to Pandy Mill a face of rock is exposed in which we find:—(1) rather cleaved felsite with many concretions, diameter about 1 inch; (2) felsite less cleaved, fewer and smaller concretions; (3) felsite irregularly jointed, somewhat cleaved; (4) felsite (?) much cleaved; (5) dark ashy rock, much cleaved. The bedding, if one can infer it from (4) and (5), appears to be nearly vertical. The next section occurs in the Lledr valley, on the left bank, about half a mile above the new viaduct. Here a mass of felsite occurs (not less and perhaps more than forty feet thick) between 'slabby' ashy slates of darker colours; nodules abound in the upper part of this rock, which forms a bold cliff with a talus of fallen blocks below. Part of the rock appears to be crowded with ovoid or almost shuttle-shaped nodules, defined in part by the bending of the cleavage-surfaces round them. Sometimes these are hollow, sometimes wholly filled by one or more of the following minerals—quartz, a brown iron oxide, and a compact dull-green flinty substance. I found, about four years since, on the slopes at the head of Llyn Idwal*, a fallen block of a similar rock which had evidently come from the crags of the Glydyr.

I proceed now to describe the above rocks more minutely, and take first a specimen of the normal felsite from a little pit close to the Conway Falls Inn. This is a compact, bluish-grey rock, weathering to a paler tint, with only a few small felspar crystals and specks of a dull green colour scattered throughout the ground-mass. Under the microscope the rock (Pl. X. fig. 1) exhibits traces of a fluidal structure. The bands, wavy or corrugated, are mainly indicated by microliths of a pale gold-green mineral, apparently of rather irregular outline. A mineral, presumably the same, occurs sparsely in small aggregated patches (the dull green specks visible to the naked eye) and resembles one of the chlorite group rather then a hornblende. The slide

* The Museum of Economic Geology, Jermyn Street, contains a specimen from the Glydyr Fawr, as well as specimens from Digoed, near Bettws-y-Coed.

contains one or two crystals of felspar, one showing plagioclastic twinning. The above microliths are present in these also, together with a speck or two of epidote and a little ferrite. The ground-mass exhibits the usual devitrified structure, which also gives some indication of a fluidal arrangement *.

Another specimen taken from about four yards lower down than the outcrop of the first nodular part differs only in its fluidal structure being more uniformly banded (fig. 6), and in giving, even macroscopically, indications of cleavage, the cracks, under the microscope, being seen to be coated with the green mineral already described. The schist-like rock is not easily cut for the microscope; but Mr. Cuttell has succeeded in preparing for me a fairly thin transverse section (fig. 3). It is more decomposed than the other specimen; but the character of the ground-mass is similar, indications of fluidal structure can still be seen, and the cleavage is marked by irregular wavy cracks, very roughly parallel with it. These are coated by a green mineral, resembling that already described, but more filmy. It is very difficult to isolate one of the folia of this sufficiently to determine its optical characters. So far as I can ascertain, it is not monoclinic or triclinic; it is doubtless a hydrous mineral, probably related to the mica group, or it is not unlike that which passes under the name of sericite. A mineral of this general character is frequent in schistose rocks. The slide includes two or three of the knots or 'eyes,' which give, as already mentioned, a marked character to the rock. These are clearly vesicles, now filled more or less completely with crystalline quartz and a dusty brown mineral (limonite, with perhaps a trace of manganese). As the cleavage-cracks bend round these, we may, I think, affirm without hesitation that we have here a vesicular rhyolitic lava which, after the cavities had been more or less filled with infiltrated chalcedonic quartz and ferrite, assumed under pressure a rude cleavage-structure, the cracks of which by further infiltration were coated with the micaceous mineral. The above-described schistose aspect of the rock, macroscopic as well as microscopic, shows that it would not be prudent to reject absolutely, without any qualification, the view which regards foliation † as a process subsequent to and influenced by cleavage; it suggests also that in some cases lavas and tuffs may have been the rocks from which certain schists have been produced.

In describing the more distinctly spheroidal masses which succeed

* The felsite from the Conway Falls, which in places exhibits a tolerably well-marked columnar structure, is a slightly greener rock, but does not materially differ from the above, except that the chloritic mineral is a little more abundant, and the rock apparently a little more decomposed. The general character of these rocks is so well rendered in fig. 2, plate xxi. vol. xxxvii. of the Quarterly Journal, illustrating Mr. F. Rutley's excellent paper on some rocks of about the same age nearer Snowdon, that I have thought it needless to give illustrations. The petrologist will readily understand the merely varietal differences from this as a type.

† See also Dr. Sorby's Presidential address, Q. J. G. S. vol. xxxvi. Some cases, however, of "cleavage foliation" I am myself disposed to regard as the result of pressure during the process of mineral change, *i. e.* as rather subsequent to it than anterior, inasmuch as the structure is produced when the crystals which occur in the foliated rock are being formed, and so in the last stage of the development.

(excepting that with the very large pebble-like concretions) it will save time to include the specimens from the Lledr valley which are similar in character. Of these two rocks I have had a series of slides prepared. The rock has now lost the schisty structure, or at any rate retains no more than gives it at the first glance an ashy aspect *. In these the ground-mass exhibits more or less clearly a fluidal structure and is devitrified. In it there have been vesicles: these (as described above) are more or less filled with chalcedonic quartz; this on the inner side of the layer frequently terminates in well-marked pyramids; the brown and the green minerals appear to have been deposited subsequently, the former being mainly an impure chalybite with some limonite †, the latter a felted mass of a chloritic mineral, which towards the margin exhibits beautiful vermicular concretions. Owing to the smallness of the individual scales the results of optical tests are not quite satisfactory to me; but I think it probably rhombohedral, and it agrees generally with the mineral which Prof. Heddle and Prof. A. Geikie ‡ recognize as delessite §. I have already noticed the peculiar ovoid or shuttle-like form assumed by these masses; this is due in part to the bending of the rude cleavage-surfaces round these harder amygdaloids (as round included fragments); but I doubt whether this is the only reason of the structure. One slide, cut transversely to the longer axis of a nodule, shows it to be bounded by a well-defined ring indicated by a dark line. Under the microscope we see that the form of the inner surface of the cavity is less regular. It is almost wholly filled with chalcedonic quartz. The dark line cuts through the matrix, the outer edge is sharp; it is defined by minute scales of the green mineral and of ferrite, as if infiltration had taken place along a crack inwards; and a vein of chalcedonic quartz cuts through it and communicates with that in the interior of the vesicle in a way which suggests that the crack defining the ring was anterior to the filling of the vesicle and to the cleavage of the rock || (see fig. 5).

* This peculiarity is noticed by the Officers of the Survey (Geology of North Wales, p. 93), who speak of it as "a very singular rock, having a felspathic base, sometimes hard and compact, and sometimes flaky; in the one case like a trap, in the other like an ash." To indicate the accuracy of this description, I may mention that until I saw it through the microscope, I thought the latter variety more probably a peculiar form of an ashy rock.

† Through the kindness of Prof. Williamson a qualitative analysis of this mineral has been made for me at the University College Laboratory by Mr. F. H. Hatch. He reports:—"Soluble in HCl.; insoluble in H_2O. Metals present: (1) Iron in proportion of ferrous to ferric $=3:1$, (2) Manganese, (3) Calcium, (4) Magnesium. Acid: Carbonic acid only." It is therefore, as I anticipated from the microscopic examination, an impure chalybite.

‡ Heddle, "Chloritic Minerals," Trans. Roy. Soc. Ed. vol. xxix p. 55.

§ Little fragments of the material containing it (always, no doubt, associated with silica) are almost exactly like fragments of greenish flint. They are, however, easily scratched, having a hardness of about 3, and are slightly unctuous to the touch.

|| One of the varieties of felsite from the Lledr valley is rather slaggy-looking, and has small irregular cavities nearly or quite filled with a brown ferruginous mineral, showing a slight approach to the schisty rock of the Conway valley.

I pass next to the mass above the Conway Falls Inn, which contains the large pebbly "concretions." The "matrix" gives, as before, indications of cleavage; and the flattened aspect of the nodules is probably due to pressure. The chief difference between this rock and the former (apart from the greater size of the nodules) is that the spheroidal boundary is more definite, giving the rock the appearance of a conglomerate, and the "pebbles" are frequently solid to the core.

From one of these, nearly three inches in diameter, I have had a slice cut; I expected to find some traces of a radial structure, deeming it a kind of spherulite; of this there is not the slightest indication. The slide (fig. 4) exhibits a wavy fluidal structure, and does not materially differ from that of the felsite obtained near the inn, showing, like it, one or two crystals of felspar and aggregations of the green mineral. The fractured face of the nodule gives indications of cracks concentric with the exterior.

I turn now to a rather similar rock, obtained several years since from the neighbourhood of Beddgelert. This also has a most singular resemblance to a conglomerate with a compact matrix. The latter is rather darker in colour than the rock we have been describing; the "pebbles" show a similar compact homogeneous aspect. One of these under the microscope exhibits the usual structure of a devitrified rhyolitic lava, except that it is rather more stained with ferrite, opacite &c., with some scattered grains of iron-oxide. The matrix has its devitrification-structure more minute; and its fluidal structure is mainly indicated by viridite*. Several parts of the slide present distinct though rude indications of a perlitic structure†.

In the lower part of the yellowish felsite, which forms the mass of Conway Mountain‡, and a short distance to the west of that town, is a thick band of spheroids which seems to run rather evenly for a considerable distance. Another band, not less than twenty feet thick (the rock here, I was informed, had been quarried for china-clay), occurs near the crest of the mountain. The spheroids are sometimes a couple of inches in diameter; they are often hollow at the core; and the more compact rock below exhibits occasional small cavities with irregular flinty-looking patches, sometimes dark, sometimes pinkish in colour: like the above-described green patches, they are rather unctuous and easily scratched with a knife.

This great mass of felsite is overlain by a grit evidently composed of materials derived from it, and sometimes by no means easy to distinguish with the unaided eye.

A similar felsite (part of the same mass displaced by a fault) forms the Diganwy Hills. The upper surface of the flow was well exposed

* The term is used advisedly; most of the mineral is not doubly refracting, and so differs from that described above. From its relation to cracks &c. it is clearly, in its present form, a mineral of secondary origin.

† See fig. 4, pl. xxi. vol. xxxvii. (illustrations to Mr. F. Rutley's paper). I have no doubt this is the second rock mentioned in Mr. G. G. Butler's note, p. 403.

‡ See Memoir, p. 107, considered, like those last described, to form a part of the great group of lava-flows so finely exhibited in Snowdon.

in 1878, opposite to the gate of the Diganwy Hotel. A little below this the felsite is also very spheroidal, the ovoid balls being often almost in contact, from 1 to 1·5 inch in diameter, and sometimes even double the latter size. Where not decomposed, they have within a cherty aspect. The structure occurs most conspicuously in a band several feet thick. Here also the surface of the mass is overlain by a grit derived from the felsite, in which pebbles of that rock occur; and then comes, apparently in immediate succession, a black slaty rock. Specimens of the spheroidal rock from the upper part of Conway Mountain, and of a spheroid from Diganwy, have been examined microscopically. Both are considerably decomposed. The outer part of the spheroid (like a kind of envelope, more regular on the outer than on the inner side) exhibits a very well-marked fluidal structure, which shows a general parallelism to the bounding surfaces, bending up into wave-like crests in the interior. This, in the former specimen, is hollow, with more or less of a lining of minutely crystallized quartz. The matrix of the rock, among the spheroids, shows also a fluidal structure; but this is more irregular and more decomposed than in the Diganwy specimen. The "husk" of this exhibits a very fine fluidal structure, rather more corrugated than in the other case; the interior is occupied by a pale brown, more homogeneous material, with occasional lacunæ. This, with crossed Nicols, exhibits many minute bright specks, with others that are colourless. It would seem as if a little of a glassy base still remained. As in places the boundary between this and the "husk" is very sharp, I have doubted whether it may not be formed by subsequent infiltration; but since in other places the one seems to pass into the other, and the structure more resembles that of a glassy rock with minute devitrification-structure, I incline to the opinion that it is merely a more compact and homogeneous form of the parent rock. These rocks, then, present us with structures resembling in some respects those already described from the felsites of the Bettws-y-Coed district*.

A specimen of the ordinary cream-coloured felsite of the Conway Mountain has also been examined. The rock is often very platy, so that it might almost be mistaken for a bedded mudstone; occasionally (as notably in a quarry near a foot-bridge which crosses the railway a little west of Conway) it is a pale greenish-grey colour, showing that the yellowish tint is the result of decomposition. Under the microscope it exhibits innumerable minute semitransparent dusty granules, and, with crossing Nicols, a patchy, very minute devitrified structure, giving indications of banding, the patches apparently composed of ill-defined microliths so arranged that each patch is approximately of one tint†.

* I have not entered into other details of the more minute mineral structures, the results of devitrification, infiltration, &c., deeming them of no very special interest.

† I have also examined the dark felsite further west, on the other side of the fault crossing the western end of Conway Mountain. It differs from those described above in having its base (I incline to the opinion that there is still a

A well-preserved flinty pale-grey felsite with nodular inclusions of quartz, in places dark green, with admixture of a chloritic mineral, may be seen in loose blocks by the road-side between Penmaenmawr and Conway. Under the microscope it shows a wavy fluidal structure, like many of the above, with a few small felspar crystals, most being orthoclase. The inclusions are vesicular cavities filled with quartz, and vermicular chlorite, like that described above, with a few tufted groups on the edge of the cavities of what appears to be a colourless mica, which also is occasionally seen in the above-described specimens. I do not know the locality where this particular variety of felsite occurs *in situ*; but doubtless it is one of those belonging to the Bala group.

From the above descriptions we are, I think, justified in the following conclusions:—

(1) That these Bala felsites are a group of ancient rhyolitic lavas, exhibiting vesicular, slaggy, fluidal, and other characteristic structures, and in no way (except as regards the effects of their great age) different from those of modern date.

(2) That the nodular or spheroidal structure has been produced in two ways:—

(*a*) By simple contraction and roughly concentric cracking of the mass in cooling, being thus intermediate between the perlitic structure common in glassy acid lavas, and the spheroidal structure common in basalt, which, so far as I know, is rather rarer in the former.

(*b*) By similar contraction in cooling, which is determined by the presence of a cavity, and produced as follows:—When the cavity is first formed, we may regard the whole viscid mass in the neighbourhood as in a state of equilibrium between the various forces acting on the cooling lava (contraction &c.) and the pressure of the gaseous contents of the cavity. As cooling proceeds (uniformly suppose) the volume of the latter diminishes rapidly, and its pressure against the walls of the cavity decreases. The various forces are no longer in equilibrium, and the contractile strain will be relieved by the formation of a crack, roughly concentric with the cavity, which, as we might expect, is more regular than it in form *.

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glassy residuum) crowded with microliths, many of elongated form, which, from their very small extinction-angles with the longer edge, I should infer to be oligoclase; but there is some orthoclase. Some longer felspar crystals are more or less replaced by a filmy transparent mineral, giving brilliant colours with polarized light, neither monoclinic nor triclinic. There is a grain or two of ilmenite (fig. 2). This rock passes into the compact greenish-grey felsite of Penmaenbach, which exhibits a somewhat similar but less definite structure, and is more decomposed. It is marked on the Survey map as intrusive. I had not time to work out its stratigraphical relations; but petrologically it has rather the characters of a flow.

* I do not remember to have noticed an instance of the presence of cavities in the spheroids of a basic rock; but Prof. A. H. Green has mentioned to me an instance observed by him on the coast of Newfoundland, where cavities partly filled with calcite, quartz, and epidote, occur in the middle of large rude spheroids in a dark trap, probably a diabase.

(3) That the cavities are then filled, wholly or partially, by infiltrated minerals in the usual way.

(4) That the nodules thus rendered more solid (and in other cases from the effect of their form, aided perhaps by extremely minute differences in texture due to the disturbance of equilibrium in cooling) produce the usual distortion of the cleavage-planes when the whole mass is compressed.

(5) That, in some cases, further infiltration takes place along the the cleavage-planes, giving rise to the schisty aspect.

At what period the devitrified structure was produced it is difficult to say. I should not wish to preclude myself from supposing that in some cases it may have been set up during the cooling of the lava. It may be well in conclusion to call attention to the occurrence of two great outbursts of rhyolitic lava in approximately the same area of North Wales, separated by so vast an interval of time as that which divides the Bala from the later Pre-Cambrian period.

EXPLANATION OF PLATE X.

Fig. 1. Felsite from close to the Conway Falls Inn, illustrating the normal condition of the rock (p. 290), ×20.

2. The dark-coloured felsite from the western end of Conway Mountain (p. 295, note), ×20.

3. The schistose felsite from the road-side above the Conway Falls Inn (p. 291), ×20.

4. Slide cut from the interior of one of the large pebble-like nodules, nearly 3 inches in diameter, in the felsite rather beyond the schistose rock of last figure (p. 293), ×50.

5. Part of a nodule, showing portion of a cavity, a boundary crack defined by a dull green mineral and the subsequent chalcedonic infiltration, a few yards below the schistose felsite above Conway Falls Inn (p. 292), ×20.

6. Felsite, about four yards lower down the road than the outcrop of the first nodular felsite (fig. 5), from the road-side above the Conway Falls Inn (p. 291), ×20.

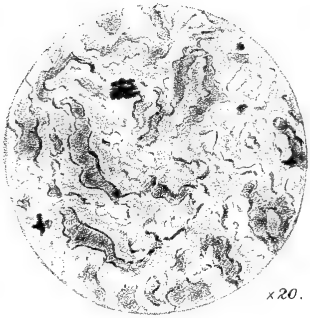
DISCUSSION.

Prof. BLAKE asked why, if the cracks were formed in the felsites in the way described, similar cracks are not found in other amygdaloidal rocks.

Rev. E. HILL asked if there were any criteria by which these altered felsites could be distinguished from true schists and gneisses.

The AUTHOR stated in reply to Mr. Blake that the conditions of rock-formation were so various that it was impossible to explain

1.

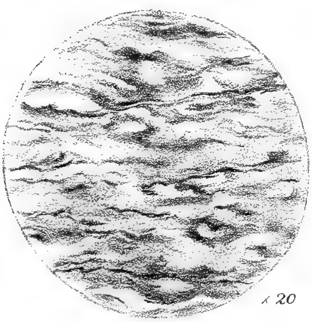


x 20.

2.

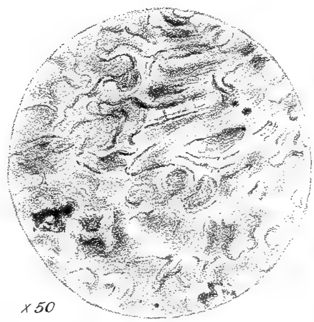
x 20.

3.



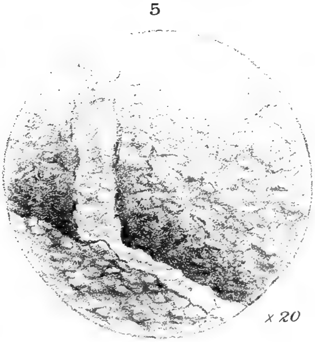
x 20

4.



x 50

5



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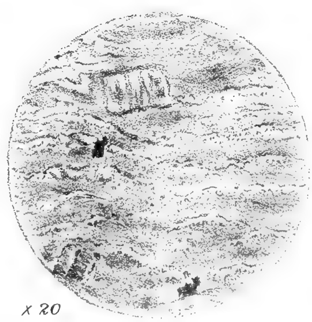
6.



x 20

A. S. Foord. del. et. lith.

Mintern Bros. imp.

BALA NODULAR FELSITES.

why all apparently similar rocks did not present the same characters. In accounting for the presence of a structure, he could not undertake to explain its absence. In reply to Mr. Hill he said that the mimicry of foliation could only deceive the unassisted eye, and disappeared when the microscope was applied to the study of the rocks.

31. *On the* Relations *of* Hybocrinus, Baerocrinus, *and* Hybocystites. By P. Herbert Carpenter, Esq., M.A., Assistant Master at Eton College. Communicated by Prof. P. Martin Duncan, M.B. Lond., F.R.S., V.P.G.S. (Read May 10, 1882.)

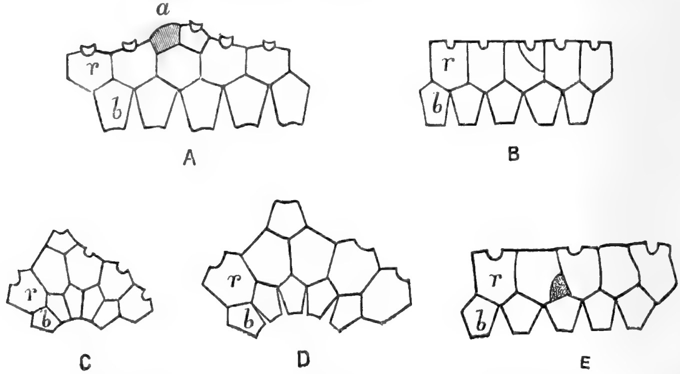
[Plate XI.]

The Crinoids from the Lower Silurian of Canada for which the genus *Hybocrinus* was established by Billings* in 1856 are remarkable for the protuberance of the anal side of the cup, so that it has somewhat of a humpbacked appearance, as is expressed in Billings's generic name. Resting on the stem are five pentagonal basals, above and alternating with which is a row of five plates (fig. I. A, and Pl. XI. figs. 3, 4, 5). Four of these are arm-bearing radials. The fifth is a hexagonal "anal," or (as I prefer to call it) azygos plate, on the right upper edge of which rests a small arm-bearing radial, while its left upper edge bears a smaller and true anal plate.

These characters are well shown in fig. I. A, which is a copy of Billings's original diagram of the genus; and also in Pl. XI. figs. 3, 4, and 5, which represent the left, right, and anal sides of a specimen from the upper part of the Trenton beds of Mercer County, Kentucky, U. S. A.

A form somewhat similar to *Hybocrinus*, though lacking the second or true anal plate, had been described some years previously by Von Leuchtenberg† under the name of *Apiocrinus dipentas* (fig. I. B;

Fig. I.—*Calyx-diagrams of* Hybocrinus *and* Baerocrinus.



b. Basal. *r.* Radial. *a.* Anal plate.

A. *Hybocrinus tumidus.* After Billings.
B. *H. dipentas,* type. After Grewingk.
C, D. *H. dipentas,* other varieties. After Schmidt.
E. *Baerocrinus Ungerni.* After Grewingk.

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* Report, Geological Survey of Canada, 1856, p. 274.

† Beschreibung einiger neuen Thierreste der Urwelt von Zarskoje Sselo (St. Petersburg, 1843, 4to.) p. 17, tab. ii. figs. 9 & 10.

Pl. XI. fig. 2). It had been found at Pulkowa, in the neighbourhood of St. Petersburg, in the Orthoceratite-limestone or "Vaginaten-Kalk" of the Lower-Silurian period; but its discovery seems to have been unknown to Billings. Had he been acquainted with it, he would assuredly have recognized its resemblance to his Canadian species, and its difference from the Mesozoic *Apiocrinus*. This last point was noticed by Schmidt*, who had met with a specimen from the same horizon at Reval in Estland; but he did not attempt to define its systematic position.

The first efforts in this direction were those of Eichwald †, who referred Leuchtenberg's specimen, together with a somewhat different one from a slightly higher horizon, the "Brandschiefer" of Erras (fig. I. E; Pl. XI. fig. 1), to the genus *Homocrinus*, Hall. The calyx of this genus, however, had been described as composed of three series of five plates each; and the difference between this character and that of the dicyclic *Apiocrinus dipentas* led Volborth ‡ to dispute the correctness of Eichwald's determination.

At the same time he established a new genus, *Baerocrinus*, for the Erras specimen, on account of its greater size, and of the differences between its calyx and arms and those of Leuchtenberg's type—though he was unable to work these out in much detail, owing to the specimen being partially obscured by matrix. On one point, however, he laid considerable stress. The suture between two of the radials and the subjacent basal is concealed by a slight triangular swelling, occupied by what appears to be about twenty minute plates. Volborth suggested that this might possibly be a madreporite or a genital organ, and hinted at a comparison of it with the ventral side of *Pleurocystites*. In fact, it seems to have been the presence of this "Volborth's Organ," as it has since been called, that was his chief reason for placing the Erras specimen in another genus than *Hybocrinus*, Billings, to which he very rightly referred Leuchtenberg's original specimen from Pulkowa and other similar ones.

A vigorous controversy now ensued between Volborth and Eichwald §. The latter insisted strongly upon the identity of the Erras and Pulkowa specimens, and defended as strongly his reference of both of them to *Homocrinus*. Volborth || replied by emphasizing the characters of *Baerocrinus*; and he (Volborth) pointed out that Leuchtenberg had only described a dicyclic calyx in *Apiocrinus dipentas*, which he regarded as a *Hybocrinus*. Eichwald ¶ answered with a diagram and analysis of the *Homocrinus*-calyx; and stated that the Pulkowa and Erras specimens agree with it most perfectly in the number of plates, "only with the difference that the two lower series** some-

* Untersuchungen über die silurische Formation von Ehstland, Nord-Livland und Oesel (Dorpat, 1858), p. 219.

† Lethæa Rossica, Band i. 1, pp. 582, 584.

‡ "Ueber *Baerocrinus*, eine neue Crinoideen-Gattung aus Ehstland," Bulletin St. Petersb. Acad. tom. viii. 1865, p. 178.

§ Bulletin de la Soc. Imp. des Nat. de Moscou, 1865, ii. p. 150.

|| *Ibid.* p. 442. ¶ Moscow Bulletin, 1866, part i. pp. 146–161, tab. viii.

** *I.e.* under-basals and basals.

times fuse with one another, and do not everywhere show the sutures quite so clearly as is represented in Hall's ideal diagram." In this point, however, lies the chief difference between the two types. The sutures are not visible in the Erras specimen (*Baerocrinus*), because they are not there (fig. I. E; Pl. XI. fig. 1); and Eichwald was driven to assume a fusion between the basals and supposed under-basals in order to support his theory of its being a *Homocrinus*. But in *Apiocrinus dipentas* he believed himself able to discern not only a suture between basals and under-basals, but also sutures between the under-basals themselves, which in his view are in the same line with the basals, and not alternating with them; and he made the curious mistake of saying that this is quite the same arrangement as in *Encrinus liliiformis* from the Muschelkalk, although, as is well known, exactly the reverse is the case.

The so-called Volborth's organ was regarded by Eichwald as due to fracture—a view which, with more or less modification, has been adopted by later writers; but his attempt to discover in the Russian specimens the interradial plates of *Homocrinus* has hardly met with such general acceptance. Neither was his refutation of Volborth's identification of *Apiocrinus dipentas* as a *Hybocrinus* at all well grounded; for it depended on the following reasoning.—Two radials are visible on one side of the Erras fossil (*Baerocrinus*). The opposite * side of the Pulkowa specimens shows three radials in a continuous series. Hence there was an unbroken series of five radials in *Apiocrinus dipentas*, which therefore could not be a *Hybocrinus*. The weak point in this argument is the assumption of the specific identity of the Erras and Pulkowa specimens, which, like Volborth and Grewingk †, I am strongly inclined to doubt; although Schmidt ‡, the latest writer on the subject, adopts Eichwald's view as regards this point. He refers both fossils to *Hybocrinus dipentas*, however, and gives diagrams of other examples of the species (fig. I. C, D), which have any thing but the continuous series of five radials that was assumed to exist by Eichwald after his examination of "opposite" sides of two very dissimilar specimens.

Eichwald's defence of *Homocrinus* was severely criticised by Volborth §, who stated that he had examined over twenty calyces of *Hybocrinus dipentas* without finding any traces of the under-basals described by Eichwald in a young but worn specimen; while he also pointed out Eichwald's mistake in localizing the under-basals of *Encrinus* as parallel to the basals, and that, if Eichwald's description of it were correct, *Apiocrinus dipentas* would represent a new type of Crinoids altogether and not belong to *Homocrinus* at all.

* How determined as opposite?

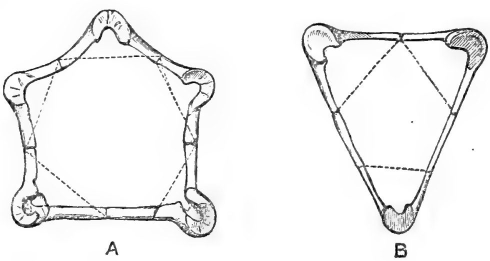
† "Ueber *Hoplocrinus dipentas* und *Baerocrinus Ungerni*," Archiv für die Naturkunde Liv- Ehst- und Kurlands, series 1, Bd. iv. p. 110.

‡ "Ueber einige neue und wenig bekannte Baltisch-silurische Petrefacten," Mem. St. Petersb. Acad. tom. xxi. no. 11, p. 5.

§ "Die angebliche Homocrinen der Lethæa Rossica," Moscow Bulletin, 1866, part iv. pp. 541–550.

In the following year (1867) this question was rendered still more complicated by Grewingk*, who was fortunate enough to succeed in removing much of the matrix that obscured the solitary specimen of *Baerocrinus* from Erras. According to his observations *Baerocrinus* is a very peculiar type, and totally different from *Hybocrinus*; for on the basals rest five radials in a continuous series, only three of them, however, bearing arms, for which purpose they are provided with distinct articular facets, while the other two radials have straight or slightly infolded upper margins but no trace of facets. This is very well shown in his side view (Pl. XI. fig. 1) and diagram of the edge of the cup (fig. II. B), to

Fig. II.—*Diagrams of* Hybocrinus *and* Baerocrinus.



A. Calyx of a typical *Hybocrinus dipentas*, as seen in outline from above.
B. A similar view of *Baerocrinus Ungerni*. The two edges of every arm-bearing radial are joined by dotted lines. After Grewingk.

which, however, he hardly refers, not seeming to attach much importance to this point. Volborth's organ was regarded by him as a monstrosity, and as in no way comparable to the ventral side of *Pleurocystites*. He gave an excellent description and figure of *H. dipentas*, the latter (Pl. XI. fig. 2) being taken from a specimen that had been found some time previously at Reval. Like Volborth, he disputed Eichwald's reference of this type to *Homocrinus*, though he did not follow him in calling it *Hybocrinus*. For he pointed out that while there are two anal plates in the American species, the Russian forms have but one; and he proposed to establish a genus *Hoplocrinus* for the reception of these last, basing the name on the hoofshaped articular facets on the radials and arm-joints†. There are five of these facets; and the outline of the calyx is pentagonal (fig. II. A), and not triangular as it is in *Baerocrinus* (fig. II. B). Arm-facets of this shape, however, are common enough in other Palæocrinoids, including the Canadian *Hybocrinus tumidus*, and in the various species referred by Hall to *Homocrinus*; and though the absence of the second anal plate may be a good character, distinguishing the Russian from the Canadian species, it hardly seems to me of sufficient importance to constitute a generic *differentia*.

Grewingk's paper naturally elicited a forcible criticism from

* *Loc. cit.* † ὁπλή.

Eichwald*, who expressed himself, however, somewhat less strongly than before respecting the identity of the fossils from Erras (*Baerocrinus*) and Pulkowa (*Hybocrinus dipentas*). For he merely says "if they are identical, as I believe them to be," and not "they are absolutely identical." It would seem, therefore, that the further knowledge of *Baerocrinus* which had been obtained by Grewingk, had raised some doubts in the mind of Eichwald as to the tenability of his former position. He also accepted Grewingk's diagram of the composition of the calyx of *Hybocrinus dipentas* (fig. I. B), but renamed it rather oddly. For the four large arm-bearing plates were called by him "parabasals," the only "radial" admitted by him being the small arm-bearing plate borne on the right upper side of the fifth or azygos "parabasal." The four other radials were supposed by him to have fused with the subjacent parabasals, although no traces of sutures remain to indicate their existence. Some such idea as this was necessary in order to be able to regard the calyx of *Apiocrinus* (*Hybocrinus*) *dipentas* as tricyclic, so as to permit of its comparison to that of *Homocrinus*; for Eichwald seems to have given up the views which he had previously held respecting its under-basals. With this granted he could of course assert that the composition of the calyx in *Apiocrinus dipentas* was the same as that of *Homocrinus alternatus*, except as regards the presence of the fifth radial and the azygos plate.

But remembering the differences between the various species of *Homocrinus* †, he did not consider the characters of *A. dipentas* sufficiently marked to be of generic value. Eichwald's expectation that specimens of *A. dipentas* would be found with the arm-bearing plates distinct from the so-called parabasals, is hardly likely to be realized.

He also objected to Grewingk's conception of *Baerocrinus* as 3-armed, after his own description of it as 5-armed, on account of this being "entirely contradictory to our fundamental conception of a Crinoid." And he further stated that "this would be a structure unique in its character, which is the less likely to have existed, because the Erras fossil is so similar to that from Pulkowa that I have referred them both to one and the same type, *Homocrinus*, and I must now assume that *both the radials* intervening between the three arm-bearing ones *have been lost, together with their arms*"(!!!). One does not wonder, after reading the above passages, that Volborth should have blamed Eichwald for straining his facts to suit his theories. It is surely no argument against the 3-armed nature of *Baerocrinus* for Eichwald to say that he believed it to be so like a 5-armed type that he described the two as identical. Neither can

* "Die Lethæa Rossica und ihre Gegner," Moscow Bulletin, 1867, vol. i. pp. 191–199.

† According to Wachsmuth and Springer ('Revision,' p. 77), Hall's generic description of *Homocrinus* "is so indefinite, that it includes almost every genus of the Cyathocrinidæ;" and *H. alternatus*, on the characters of which Eichwald laid so much stress from its supposed resemblance to *Apiocrinus dipentas*, is really a *Dendrocrinus*.

it be established by Eichwald's dictum that if *Baerocrinus* were only 3-armed it would only have three parabasals, while as a matter of fact five are present. But five can only be counted on the supposition that the three arm-bearing plates are primitively double, for which Eichwald had no warrant whatever, except that it was necessary to support his theory; and although the number five "does so predominate in the structure of all Crinoids that it is to be regarded as a fundamental law determining their general form," yet there are many well-known exceptions to the rule.

Schmidt* appears to accept as correct Grewingk's description of *Baerocrinus* as only 3-armed; but he regards it only as an abnormal and imperfect specimen of *Hybocrinus dipentas*. He has examined a specimen from the "Jewesche Schicht" of Altenhof, which has five arms with all the characters of those of *Baerocrinus*, while its calyx is that of *Hybocrinus dipentas*, and is without any trace of a Volborth's organ. He has also met with three examples of the latter species in which there are only four arms (fig. I. D), the right anterior one remaining undeveloped; and he seems to regard these as affording a connecting link with *Baerocrinus*, which genus he, like Eichwald, absorbs into *Hybocrinus dipentas*.

It is perhaps rash for one who has not seen any of the specimens to attempt to form an opinion on this much disputed question. But, after a careful consideration of all the evidence, I venture to offer the following conclusions for what they may be worth.

There can, I think, be little doubt that Volborth and Schmidt were right in referring *Apiocrinus dipentas* to *Hybocrinus*; but this necessitates a modification of Billings's definition of the latter genus. The American examples have two "anal" plates, while in *H. dipentas* there is only one, which, however, is probably equivalent to the two present in Billings's species. This point seems to have escaped the notice both of Zittel† and of Wachsmuth and Springer‡, who quote *Apiocrinus*, Leuchtenberg, and *Hoplocrinus*, Grewingk, as synonymous with *Hybocrinus*, without, however, making any alteration in Billings's diagnosis of *Hybocrinus* in this respect.

In the American species of *Hybocrinus* the small right posterior radial is rather above the level of the other four (fig. I. A; Pl. XI. figs. 4, 5); but in the type of *H. dipentas* it is more nearly in a line with them, though resting principally upon the large azygos plate (fig. I. B; Pl. XI. fig. 2). In one specimen from Pawlowsk, however, the small radial rests equally on the azygos plate and on the right anterior radial, and is consequently somewhat raised above the general line of the radials (fig. I. C). As already pointed out by Schmidt, this affords a transition to the 4-armed individual already mentioned, which differs from it only in the absence of a right anterior arm (fig. I. D). The plate which would naturally bear this arm has no facet upon it, so that the small right posterior

* *Loc. cit.* pp. 5–8.

† Handbuch der Paläontologie, vol. i. p. 350.

‡ Revision, vol. i. p. 74.

radial is supported upon two armless plates, the left one of which is the true azygos plate. This may be, and probably is, one of the variations of growth to which this early and simple type is subject. A somewhat similar case occurs in *Allagecrinus**, some small individuals having but three distinct arm-facets, with an imperfect fourth one, but none at all on the fifth radial. In each case, however, the varieties are generically identical. On the other hand, *Baerocrinus*, if rightly described by Grewingk (fig. I. E; Pl. XI. fig. 1), represents to my mind an altogether different generic type, although it is regarded by Zittel and Wachsmuth, as well as by Schmidt, as synonymous with *Hybocrinus*. For the calyx consists of but ten plates, which are arranged in two alternating rows without any indication of anal plates. This does not agree at all with Billings's analysis of the *Hybocrinus*-calyx.

Further, the outline of the *Baerocrinus*-calyx is triangular (fig. II. B), and not pentagonal, as is that of *H. dipentas* (fig. II. A), while only three of the upper series of plates bear arms, and there is no anal plate like that of *Hybocrinus*. In face of the great difference between the characters of the two calyces, which, however, is described by Schmidt as a "general correspondence," I prefer to regard *Baerocrinus* and *Hybocrinus* as distinct types. The similarity of the arms on which Schmidt insists seems to me to be a comparatively unimportant character; and his suggestion as to the loss of a fourth arm-bearing plate from the Erras fossil, which would render it more similar to *Hybocrinus*, is, I think, hardly warranted by the condition of the specimen. If one be supposed lost, why not two, one from the upper face of each armless plate? and even if one were missing, it is not easy to see where it could be inserted so as to make the calyx look like that of a *Hybocrinus*.

If, then, as seems to me probable, *Baerocrinus* is generically distinct from *Hybocrinus*, it occupies a somewhat unique position among the Crinoidea. It is, perhaps, best regarded as a permanent larval form which has only developed three of its five arms. I can naturally offer no opinion respecting "Volborth's organ," which is attributed by Schmidt, the latest writer on the subject, to purely mechanical causes; but it has struck me as possible that it may represent the anal opening, which does occupy a somewhat similar position between the radials and basals at one period of Crinoid development. Should this ever turn out to be the case, Volborth will not have been so very far wrong after all; but the true nature of *Baerocrinus* must remain somewhat uncertain until other examples of it are met with.

Of the three species of *Hybocrinus* described by Billings, two occur in the Trenton Limestone at Ottawa, and one in the Chazy Limestone. But the differences of the latter from the *H. tumidus* of the Trenton group are so slight that Billings† had "much doubt as to the propriety of separating it therefrom." It is, however, retained as a distinct species in Messrs. Wachsmuth and Springer's

* Ann. & Mag. Nat. Hist. ser. 5. vol. vii. pp. 282–289, pls. xv. and xvi.

† Canadian Organic Remains, Decade iv. p. 24.

'Revision,' from which, curiously enough, the Russian *Hybocrinus dipentas* is omitted.

Although *Hybocrinus* was discovered in Canada as long ago as 1856, it has not been met with in the United States until quite recently. Prof. A. G. Wetherby* has obtained it, however, together with some other most remarkable Echinoderms, from a silicified limestone near the top of the Trenton group in Mercer County, Kentucky. One specimen of *H. conicus* was found, and sixteen of *H. tumidus*, of which last Prof. Wetherby gives four excellent figures. He describes the upper azygos plate as rounded and crenulated at its distal extremity, as well as much thickened, and goes on to say that "the form of the plate is sufficient evidence that it supported a strong ventral sac, and the crenulated condition of the articulating upper surface of this plate indicates the place of the lower exterior openings into this sac." I think it probable enough that the anal plate of *Hybocrinus* did support a strong ventral sac, as suggested by Prof. Wetherby; but its upper surface can hardly be described as "articulating." It has no articular facet with fossæ for the attachment of muscles, such as occur on the terminal surfaces of the ray- and arm-plates; and it is only when there is a movable joint of this kind between any plate and the one above it that its upper surface can be properly described as "articulating." Such an articular surface occurs on the radials of *Hybocrinus*; but there is nothing of the kind on the anal plate. In a specimen kindly sent to me by Mr. Wachsmuth, I find the upper third of this plate to be somewhat thickened; and the outer face meets the nearly vertical inner face along a curved but tolerably sharp edge, on which I can make out little or no trace of crenulation. Somewhat below the middle of this edge there rises from the inner surface of the plate a little nipple-shaped projection, which may, perhaps, indicate the position of the anal tube.

Hybocrinus is a Crinoid of a very embryonic type. The relatively large size of the basals and the retention of the anal plate, together with the simplicity of its arms and the absence of pinnules, all indicate its low stage of organization. The typical forms of the Russian species (fig. I. B; Pl. XI. fig. 2) differ from the American ones (fig. I. A; Pl. XI. figs. 3–5) in having only a single anal or azygos plate. This supports the small right posterior radial on the one side; but the other (left) side bears no second anal plate, though the whole plate may be readily regarded as equivalent to the combined large and small anal plates of *H. tumidus*.

The position of the large azygos plate in line with the four larger radials is a very striking feature in this genus. Wachsmuth† has pointed out that the small radial which it bears "evidently corresponds to the upper half of the compound plate in *Dendrocrinus* (fig. III. A), while the lower half, which is here apparently absent, is perhaps represented in a portion of the large undivided anal

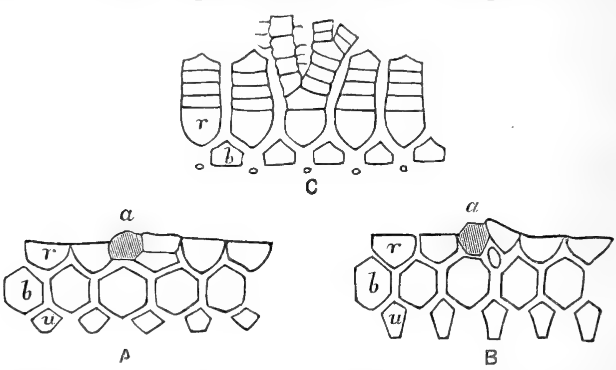
* "Remarks on the Trenton Limestone of Kentucky," Journal Cincinn. Soc. Nat. Hist. vol. iii. July 1880.

† Revision, part i. p. 74.

plate." An intermediate stage between the two is afforded by *Homocrinus* (fig. III. B), which differs from *Dendrocrinus* "only in having the suture between the sections of the compound plate sloping instead of horizontal. By this, in itself, trifling alteration, which required no modification in the form or construction of other plates, the lower portion of the original compound radial became transformed into an anal plate." It is in fact "pushed slightly to the rear, thereby becoming a regular anal plate or support for the ventral sac"*.

While entirely concurring in the views of Messrs. Wachsmuth and Springer respecting the mutual relations of *Hybocrinus*, *Homocrinus*, and *Dendrocrinus*, I am not altogether in accordance with them as to the relations of these three types to *Iocrinus*. They have given us an interpretation† of the calyx of this type, which differs considerably from that given by Hall and by Meek and Worthen. I can offer no opinion upon this point; but, assuming that their analysis of the *Iocrinus*-calyx is the right one (fig. III. C), I cannot follow their comparison of it with *Dendrocrinus*. The bifurcating plate, which gives rise both to the right posterior ray and to the ventral tube, is regarded by them as a brachial with interradial functions; and they refer to *Dendrocrinus* as illustrating this point. As the plate in question is supported on the right posterior radial, and is "of the same width as the other brachials, and apparently similarly articulated," it is probably to be considered a modified brachial. But the lower half of the compound radial of *Dendrocrinus* (fig. III. A), to which it is compared by

Fig. III.—*Diagrams illustrating the Anal System of the* Cyathocrinidæ. Copied from Wachsmuth and Springer.



r. Radial. *b*. Basal. *u*. Underbasal. *a*. Anal system.
A. *Dendrocrinus*. B. *Homocrinus* (emend., W. & S.).
C. *Iocrinus* (fide W. & S.).

Wachsmuth and Springer, rests on two basal plates, and supports the right posterior radial, which itself bears the brachials. There

* Revision, pp. 66, 78. † *Ibid.* p. 65.

is, therefore, no "articulation" between it and a radial plate below, as is the case with the bifurcating plate of *Iocrinus*; for it is united to the basals by suture; and, being *below* an arm-bearing radial, it can hardly be considered a modified brachial, *i. e.* as belonging to the series *above* the radials. It should be so considered, however, if it is to be comparable to the bifurcating plate of *Iocrinus* in the manner suggested by Wachsmuth and Springer. I cannot, therefore, follow these authors in regarding *Iocrinus* as the starting-point from which the development of the anal plates may be traced from one genus of the Cyathocrinidæ to another.

Viewed in a purely embryological aspect, *Cyathocrinus*, or a Dendrocrinoid form with the two halves of the "compound radial" united, is a lower type than *Iocrinus*. For the continuous line of the radials is broken into by the anal plate, which is in direct contact with a basal, as in the early Pentacrinoid. But in *Iocrinus*, although it is "one of the earliest known forms of Crinoids, we find the body up to the top of the radials perfectly equilateral, all basal and radial plates having the same form;" and this symmetrical condition is only attained comparatively late in the development of the recent Crinoid.

The lower part of the compound radial of *Dendrocrinus* (fig. III. A) seems to me to be fairly represented by the large "anal" plate of *Hybocrinus tumidus* (fig. I. A), and not by a portion of it only, as supposed by Wachsmuth and Springer. Resting, as it does, on the basals in a line with four very similar radials, it should, I think, be regarded rather as a modified radial, the arm-bearing portion of which has been cut off, than as a true "anal" plate; and I should therefore prefer to speak of it as the "azygos" plate. But I am bound to say that the condition of the Russian species (fig. I. B), which appears to have no separate anal plate, may be thought to prove the contrary. That the anal and the azygos plates of *H. dipentas* may have fused, as suggested by Schmidt, is possible enough; but the comparison of C and D, fig. I., seems to me to show that, like its fellow on the right, the azygos plate is fundamentally a modified radial belonging to the right posterior ray.

These conclusions are supported, I think, by the results of my study of *Hybocystites problematicus*, Wetherby, which is certainly one of the most remarkable fossil Echinoderms yet discovered. Both Prof. Wetherby and Mr. Wachsmuth have been good enough to send me specimens for examination, with a liberal kindness for which I owe them my heartiest thanks. Characters seem to me to be present in all three specimens which have hitherto escaped notice, and are of very considerable morphological importance. No two of them are exactly alike; and I have therefore thought it worth while to supplement Prof. Wetherby's representation of the type by a series of figures which have been executed with the greatest possible care by my friends Messrs. C. Berjeau and P. Highley.

Hybocystites problematicus, the only species at present known,

was discovered by Prof. Wetherby*, together with *Hybocrinus*, in the Trenton beds of the Kentucky river-section already referred to. He speaks of it as the first fossil found "which so closely unites characters both of the Crinoidea and Cystoidea, with the reference of the former characters to those of an undoubted Crinoid of very near relationship." The Crinoid in question is *Hybocrinus*; and according to Prof. Wetherby the resemblance is "so striking, that the sexual question is at once suggested as between the two." His generic description of this remarkable fossil is as follows.—"General outline of the body very similar to that of *Hybocrinus tumidus*, Billings. It consists of series of plates, five each in the first two, arranged as in *Hybocrinus*. As in that genus, the lower azygos plate bears a second and a radial upon its upper face. Arms three, one upon each side of the upper azygos plate, and one immediately opposite it. The plates of the upper series between these arms, on either side, are excavated by a groove that is continued downward, and half or two thirds across the plate of the lower series beneath it. These grooves meet in the vault at a common point with those of the arms, and form a part of the ambulacral system.

"The mouth, or ambulacral orifice, is situated nearly centrally upon the upper surface. The valvular anal opening is placed between the upper azygos plate and the mouth. The arms are deeply furrowed, the grooves being covered by a series of cuneiform interlocking plates. Pinnulæ not observed. Proboscis or ventral sac indicated by the presence of the upper azygos plate. Column small, round, and placed excentrically as in *Hybocrinus*. Vault covered by plates, of which the arrangement cannot be determined. There are no evidences of pectinated rhombs or poriferous plates. This genus combines in a remarkable degree characters both of the Crinoids and Cystids."

"*Remarks*.—The almost perfect identity of the arrangement of the plates with those of *Hybocrinus*; the three arms; the two ambulacra running down the sides of the body, as in the appressed arms of many Cystideans; the valvular anal opening; the presence of a proboscis or ventral sac, as indicated by the prominent azygos plate; and the uncovered area of the vault adjacent to it, all taken together, form a mixture of characters not united in any fossil of this difficult class hitherto described. I have referred it to the Cystideæ with some hesitation, but mainly on account of the anomalous arrangement of the ambulacral system, three rays of which are upright and two appressed, and on account of the position of the anal opening, which is the same as that in *Agelacrinites*, *Hemicystites*, and *Caryocrinus*, with the slight modification in position caused by the presence of a ventral sac."

It will be understood from the above description that Prof. Wetherby considers *Hybocystites* as possessing three arms like those of the Crinoids, and two appressed ambulacra such as occur in the Cystids. As regards the latter I am quite in accordance with him;

* *Loc. cit.* pp. 6–9.

but I would point out that they are almost equally comparable to the ambulacra of the Blastoids; and I am inclined to think that the relations of *Hybocystites* are rather with this group and with the Crinoids than with the Cystids. For I cannot make out that it had any arms at all, in the ordinary acceptance of this term in Crinoid anatomy. In the only figure* which shows any thing of the arms described by Prof. Wetherby, two joints only are represented above the radials (Pl. XI. fig. 6); and he nowhere speaks of having found any specimen with a larger number of arm-joints still in connexion with the calyx, such as are shown in his figure of *Hybocrinus*.

But he describes "a more or less obscure furrow" upon the outer surface of each arm, "of which nothing further is known."

This furrow is in reality a recurrent ambulacrum, as may be seen in figs. 8–24. It is most clearly seen in figs. 8, 14, and 20, which respectively represent a direct view of the anterior ambulacrum in each of the three specimens. They should be compared with figs. 9, 12, 15, 18, 21, 23, representing identical views of the right and left anterior ambulacra, viz. the appressed ones, to which they are similar in all respects.

I believe the supposed "arms" to be merely upward prolongations of the radials, which are possibly more or less segmented in the same way as the downward-extending radials are in *Pentacrinus briareus*. There seems, however, to be much variation in this respect; for while two segments seem clearly visible in the left posterior ray of Wachsmuth's smaller specimen (figs. 20, 21, 23, 24), there are but faint traces of grooves marking off a second segment in either of the other two rays. In Prof. Wetherby's specimen, again, delicate lines are visible crossing the radial extensions; but I have great doubts as to whether they are really to be regarded as indicating segmentation.

Of the five ambulacra, therefore, which diverge from the peristome, the right and left anterior ones pass directly downwards from the summit onto the corresponding radial plates, and from them onto the basals as described by Prof. Wetherby. The other three ascend the inner faces of the short radial extensions, pass over their tops, and down their outer faces. They are least visible in Wachsmuth's larger specimen (figs. 14–19), which has lost the upper ends of its radial extensions. But in his smaller one the two posterolateral ambulacra are very distinct (figs. 23, 24), more so in fact than the appressed anterolateral pair; and they are to be seen, though not clearly, passing over the upper ends of the radial extensions on the way from their inner to their outer faces. This feature is best seen in Prof. Wetherby's specimen, as is shown in fig. 10.

In reference to this question, I may mention that I have shown these specimens to several palæontologists, including Mr. R. Etheridge, F.R.S., and his accomplished son, and also to other naturalists who have made a special study of Echinoderm structure. All of them, I am glad to say, have confirmed my interpretation of the "more or less obscure furrows" upon the outer surfaces of the

* *Loc. cit.* pl. v. fig. 1*a*.

"arms" of this type as recurrent ambulacra similar to those of the anterolateral rays.

One very striking feature about these ambulacra is the great variation in their length and in the relative position of their distal ends. Thus in Prof. Wetherby's specimen the anterior ambulacrum (figs. 8, 11) passes down over the surface of its radial, and is continued onwards almost as far as the attachment of the stem, exactly occupying the position of the suture between the two anterior basal plates. But in both the other specimens (figs. 14, 17, 20, 22) it ends on the radial without reaching the basals at all. In the one it terminates almost exactly above the anterior basal suture (figs. 20, 22), while in the other (figs. 14, 17) it is slightly displaced towards the left side.

The two anterolateral ambulacra (figs. 9, 11, 12; 15, 17, 18; 21, 22, 23) pass down onto the basals in all the specimens, just as described by Prof. Wetherby; but they vary considerably in other respects. That on the right side occupies nearly the same relative position in Wetherby's specimen (figs. 11, 12) as in Wachsmuth's smaller one (figs. 22, 23). In both cases the ambulacrum bends slightly backwards as it passes over the radial, though in the former it ends rather further behind the suture of the right and right anterior basals than it does in the latter. In Wachsmuth's larger specimen, however, (figs. 17, 18) the backward curvature is stronger and more continuous, very much as in Prof. Wetherby's fig. 1*a*. It does not pass into a forward curve again; and the suture between the subjacent basals is quite obscure, so that the base appears to consist of four unequal plates.

In the characters of the left anterior ambulacrum, on the other hand, Prof. Wetherby's specimen (figs. 9, 11) agrees with Mr. Wachsmuth's larger one (figs. 15, 17). In each case the ambulacrum comes down onto the left posterior basal; but it is distinctly longer in Wetherby's specimen, and has a trace of a forward curve, which is absent in the other. In Wachsmuth's smaller specimen (figs. 21, 22), however, this ambulacrum comes right down onto the suture between the two left basals, so as to conceal all but a trace at its central end.

Passing now to the right posterior ambulacrum, we find another resemblance between Wetherby's specimen (figs. 12, 13) and Wachsmuth's smaller one (figs. 23, 24) in the ambulacrum passing from the surface of the small radial onto the azygos plate. This appears to me to support the view that this plate in the analogous form *Hybocrinus* really belongs to the radial series, and is not to be regarded as an anal plate like the smaller one supported upon it. The ambulacrum is slightly longer in Wetherby's specimen; but in both cases it is visible in a view of the calyx from below (figs. 11, 22). In Wachsmuth's larger specimen, however, it does not extend onto the azygos plate at all (figs. 18, 19), and is therefore invisible in a dorsal view (fig. 17).

The left posterior ambulacrum is also invisible from below, though it does extend downwards for a short distance onto its

radial (fig. 19). In the other two individuals, however, it comes far down onto the radial (figs. 9, 13, 24), and is visible on the dorsal aspect of the calyx (figs. 11, 22). But its course is different in the two cases. In Wetherby's specimen it bends considerably backwards, and terminates above the posterior basal (figs. 11, 13); whereas in Wachsmuth's specimen its distal portion turns slightly forwards, so as to end a little way in front of the suture between the left posterior and the posterior basals (figs. 22, 24).

These three individuals not only exhibit a great amount of instability in the characters of the ambulacra, but the component plates of the calyx present occasional deviations from their ordinary symmetrical form, as is evident from a glance at the figures. The most striking case is on the right side of Wachsmuth's larger specimen (fig. 18), its radial departing considerably from the hexagonal form which it presents in the other two specimens (figs. 12, 23); while the basals are correspondingly modified, and the sutures between them obscured. In like manner the suture between the anal plate and the small radial is obscured in Wetherby's specimen (fig. 13); and the upper boundaries of the radials are in nearly all cases very difficult to define. Occasionally, however, (figs. 14, 15, 16, 20, 21) there seem to be traces of oral plates between the ambulacra, somewhat as in *Cyathocrinus.*

In Mr. Wachsmuth's larger specimen (fig. 16) there are traces of small pits in the summit, as to the nature of which it is difficult to decide. If they really mean any thing, and the summit be an oral pyramid, they may possibly represent the water-pores like those in the Pentacrinoid larva of *Comatula.* I can, however, find no trace of them in either of the other specimens, and have therefore considerable doubt as to their possessing any real morphological value. Failing these, I can find no trace of any respiratory organ in *Hybocystites*; and I am therefore less disposed than is Prof. Wetherby to refer it to the Cystidea, though its appressed ambulacra give it a certain resemblance to some forms of that group. But their relation to the radials is far more like that of the ambulacra of the Blastoids. These, however, are usually broader than in *Hybocystites,* and have various accessory structures that are as yet unknown in this type. Of the ambulacra of the Silurian *Stephanocrinus* we unfortunately know but little. They were at any rate narrow, and possibly devoid of hydrospires. *Troostocrinus Reinwardtii,* the earliest Blastoid which is satisfactorily known, has narrow linear ambulacra not unlike those of *Hybocystites*; but they cover the hydrospiral tubes, as to the presence of which in *Hybocystites* we know absolutely nothing. The latter type differs from all known Blastoids in the extension of the ambulacra onto the basal plates; while its calyx presents the most striking analogy with that of *Hybocrinus.*

It differs from the Crinoids, however, in the absence of true arms, and in the singular relations of its ambulacra. The course of three of them, up one face of the radial extension and down the other, may perhaps be explained by a reference to *Cupressocrinus,*

which has many Blastoid affinities. In the variety *minor* of *C. abbreviatus* there are only two arm-joints. If the second one be imagined as bent back upon the first so that the flattened dorsal surfaces of the two joints met and united, the result would be a morphological condition somewhat similar to that of *Hybocystites.* It would have most resemblance to the condition of the right posterior ambulacrum in Wachsmuth's larger specimen (fig. 18). As pointed out above, this ambulacrum does not come down onto the large azygos plate, which I regard as a modified radial, any more than the recurved ambulacrum of the *Cupressocrinus* "arm" would pass onto the radial below it. If I understand Wachsmuth's writings aright, this is somewhat the view which he takes of the ambulacra of the Blastoids generally, one, however, which I do not altogether share, for reasons which will be explained elsewhere.

Thus, then, I regard *Hybocystites* as combining Blastoid rather than Cystidean characters with those of the Crinoids; though I should hesitate for the present to refer it to the Blastoidea, which form on the whole a fairly compact group possessing certain well-defined characteristics.

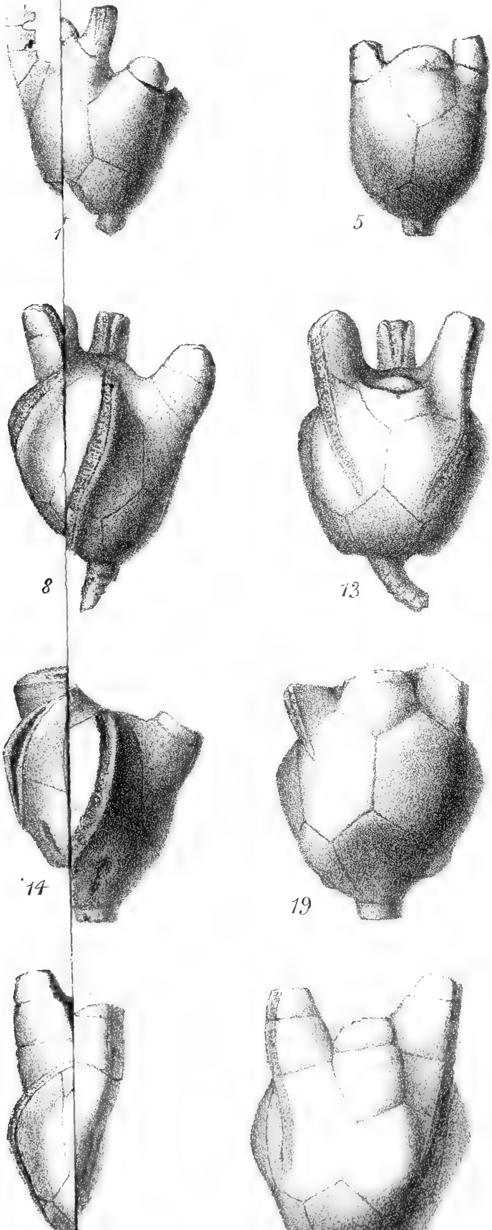
Hybocystites is only one among many palæozoic Echinoderms to which no definite position can as yet be assigned. It is much to be hoped that other and better specimens of this remarkable type may soon be discovered, so that some light may be thrown upon the many structural characters respecting which we are as yet altogether in the dark.

EXPLANATION OF PLATE XI.

Fig. 1. *Baerocrinus Ungerni*, slightly restored. After Grewingk.
2. *Hybocrinus dipentas*, anal side. After Grewingk.
3 to 5. *Hybocrinus tumidus*, × 1½. Trenton Limestone, Kentucky. 3, left side; 4, right side; 5, anal side.
6–24. *Hybocystites problematicus*. Trenton Limestone, Kentucky.
6, 7. Copied from Wetherby; fig. 6, right side, × 2; fig. 7, anal side, natural size.
8–13. Prof. Wetherby's specimen, × 2. 8, front view; 9, left side; 10, summit; 11, dorsal aspect; 12, right side; 13, anal side.
14–19. Mr. Wachsmuth's larger specimen, × 2. 14, front view; 15, left side; 16, summit; 17, dorsal aspect; 18, right side; 19, anal side.
20–24. Mr. Wachsmuth's smaller specimen, × 3. 20, front view; 21, left side; 22, dorsal aspect; 23, right side; 24, anal side.

Discussion.

Dr. Carpenter said that the paper contained very carefully worked out descriptions of a curious osculant form between the Blastoids and the ordinary Crinoids, which were in process of discovery in the older rocks, especially in N. America. He was glad that his son had devoted himself, with such good results, to the study of these difficult forms, at which he had once worked himself; and he thanked the Society for the cordial welcome which they had always accorded him.



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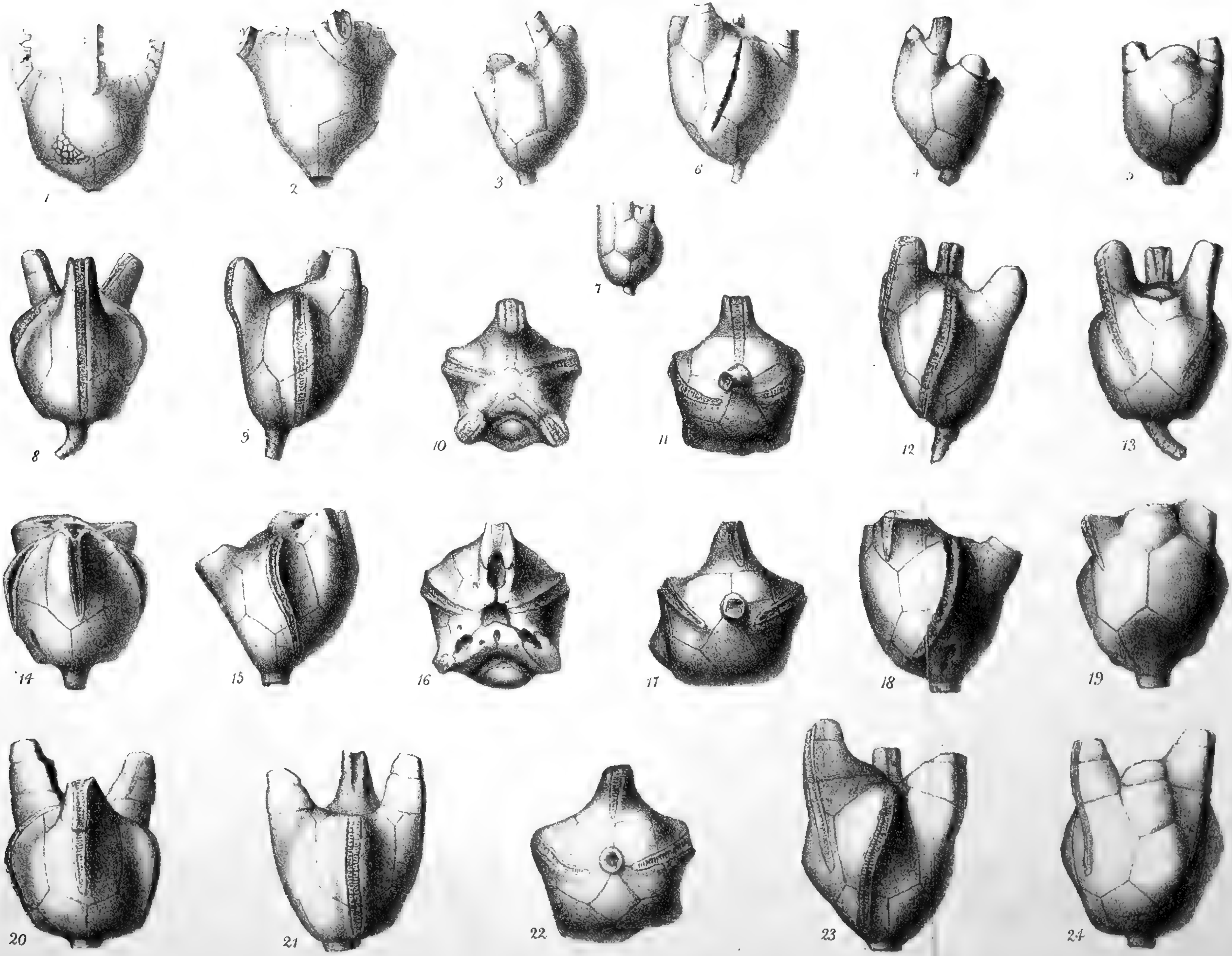

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HYBOCYSTITES PROBLEMATICUS.

32.—*On the* Cambrian (Sedgw.) *and* Silurian Rocks *of* Scandinavia. By J. E. Marr, Esq., B.A., F.G.S.* (Read April 5, 1882.)

Contents.

1. Introduction.
2. Description of the strata.
3. Comparison of the strata with the British and Bohemian deposits.
4. Migrations of the faunas.
5. Summary.

§ 1. *Introduction.*

The Cambrian and Silurian rocks of Scandinavia occur in isolated patches among the older granites and gneisses of the peninsula; but the various strata of these patches have been correlated by many geologists (notably by the late Dr. G. Linnarsson); for their lithological characters continue nearly unaltered over many thousand square miles of ground. The strata are generally very little disturbed and faulted (an exception to this statement must, however, be made in the case of the Dalecarlian beds), and cleavage is very exceptional; hence the organic remains are usually well preserved. The great interest of the latter is due to the fact that many of them are found in shallow-water beds, deposited at periods when the greater part of the North-western European area was covered with deep water.

In a paper read before the Society on the ninth of June 1880, whilst the "Colonies" theory of M. Barrande was considered at some length, I merely referred to the instances of migration shown by the eminent palæontologist to have occurred in the Bohemian area. In the present communication I intend to treat more of the phenomena of migrations; and as these, unlike the Bohemian "colonies," lend support to the nomenclature of Prof. Sedgwick, his classification of the Cambrian and Silurian rocks is here adopted.

My hearty thanks are due to many geologists, among whom I may mention Dr. Sven Törnqvist (under whose guidance I visited the principal sections of Dalecarlia), Prof. Lindström (for kind assistance in the Museum of the Academy of Science, Stockholm), Mr. Brögger of Christiania, Prof. Johnstrup of Copenhagen, Prof. Lundgren of Lund, and Dr. Tullberg. My thanks are again due to Profs. Hughes and Bonney for much kind assistance.

§ 2. *Description of the Strata.*

It will be most convenient to describe separately the strata of the different areas which I have examined, in the order in which they

* [The author gratefully acknowledges a second grant from the Worts Travelling Scholars' Fund of the University of Cambridge, "to enable him to travel in Norway, Sweden, and the islands of the Baltic, and collect evidence and specimens bearing upon the question of the classification of the Cambrian and Silurian Rocks" (Grace 3, Apr. 15th, 1880).]

were visited, *i. e.* commencing in the north-east, and proceeding towards the south-west, or generally from shallow-water formations to those deposited in deeper seas. The following are the different areas examined:—I. Dalecarlia; II. Ostrogothia and Westrogothia; III. Christiania; IV. Scania; V. Baltic Islands.

I. *Dalecarlia* (*Dalarne*).—The Cambrian and Silurian rocks of this province occur in the neighbourhood of Lake Siljan and the smaller surrounding lakes, and are encircled by granites and gneissose rocks. These beds have been described by many authors, including Sir R. I. Murchison (Q. J. G. S. vol. iii. p. 1); but since his description, the fullest details have been worked out, notably, by Dr. Sven Törnqvist. The general succession of the beds is given by him (Öfv. af Kongl. Vet.-Akad. Förhandl. 1874, No. 4, p. 38) in descending order, as follows:—

Leptæna-limestone.
Upper Graptolite-shales.
Trinucleus-shales.
Grey limestone.
Cystidean limestone.
Orthoceras-limestone.
Obolus-beds.

Below the latter is the unfossiliferous "Slip-sandsten." This consists of white, brown, and pink grits, conglomeratic at the base, and deposited upon gneissose and other rocks. It was evidently laid down in shallow water, and is frequently found faulted against much newer beds.

Obolus-beds.—These beds are divided by Törnqvist into a lower conglomerate and upper limestone. They rest unconformably upon older rocks. Both conglomerate and limestone contain worn valves of an Oboloid shell, and are also crowded with glauconitic grains. The conglomerate, as stated by Törnqvist, also contains phosphatic nodules. At Vicarbyn, on Lake Siljan, the conglomerate rests upon granite, and contains pebbles about the size of a pigeon's egg, both matrix and pebbles being composed of granitic materials. The Obolus-beds are well seen near Boda, in some old lead-workings on the hillside a few hundred yards E. of the church, where they present the same characters as at Vicarbyn, and pass up into the Orthoceras-limestone.

Orthoceras-Limestone.—A great series of thin-bedded limestones divided by Törnqvist (*loc. cit.*) into five groups:—Upper grey limestone, upper red limestone, lower grey limestone, lower red limestone, and green glauconitic limestone. The last named is well seen at Vicarbyn, where it contains very large grains of glauconite. Above this is a red bed, containing a few glauconitic grains somewhat decomposed: this is important as seeming to bear out the supposition of Profs. Seeley and Bonney that certain red rocks, such as the Hunstanton Red Chalk, owe their colour to the peroxidation of glauconitic grains. At Kärgårde, near Orsa, a bed in the lower grey limestone is crowded with brown oolitic grains. The upper

red limestone at Skattungbyn contains a band of red shale from half an inch to one inch in thickness, very rich in fossils, which are of considerable interest, and will be referred to more fully when considering migrations. I found here :—

Beyrichia, sp.	Remopleurides radians?
Turrilepas.	Trinucleus.
Agnostus trinodus, var.	Orthis.
Æglina (eye of).	Acrotreta.
Acidaspis.	Gasteropods.
Lichas.	

All these fossils are very minute, and seem to have lived under conditions unfavourable for the existence of marine life.

The Orthoceras-limestone at Fjecka is succeeded by a grey limestone with shaly partings: this bed is considered by Törnqvist to be a passage-bed between the Orthoceras-limestone and the succeeding Cystidean limestone; it contains an admixture of the faunas. A similar bed occurs at Furudal, where shaly partings contain *Diplograptus*.

Cystidean Limestone.—A grey nodular limestone, usually crowded with Cystideans, mostly in a poor state of preservation, well seen at Vickarbyn, Kärgårde, Fjecka, and Furudal.

Between the Cystidean limestone and the Trinucleus-shales are two series of beds which have not yet received distinctive names, but have been described by Törnqvist (Öfv. af. K. V.-Akad. Förh. 1874, No. 4, p. 16). The lower series immediately succeeds the Cystidean limestone, and passes into it. It consists of greenish grey calcareous shales, with calcareous nodules. This series is found at Kärgårde and at Fjecka. A list of fossils is given by Törnqvist, to which I may add *Turrilepas* and *Beyrichia strangulata*, which I found at Kärgårde. The succeeding series consists of hard grey limestones, in which fossils are very rare: it is seen at Fjecka, apparently underlying the old grey marls (all the beds at this place being reversed).

Trinucleus-Shales.—Black shales, crowded with fossils, and containing hard unfossiliferous limestone bands, succeeded by red calcareous fossiliferous shales. These beds are seen in many sections, as at Vickarbyn, Skattungbyn, Fjecka, and Gulleråsen. In the paper already referred to, Törnqvist gives lists of the higher organisms; and in another paper (Geol.-Fören. i Stockh. Förh. 1879, Fo. 56, Bd. iv. No. 14, p. 448) he records *Diplograptus pristis*, His., *Dicellograptus anceps*, Nich., and *D. elegans*, Carr., from these beds.

Upper Graptolite-Shales. These have since been divided by Törnqvist (Geol. Foren. Förh. 1875, No. 10) into the lower or Lobiferus-shales, and the upper or Retiolites-shales.

The junction between the Lobiferus- and Trinucleus-shales is nowhere seen at present. At the north end of the village of Gulleråsen, the red beds of the Trinucleus-shales are seen at one side of a stream, and the Lobiferus-shales at the other; and there is no evidence of a fault between them. The lowest beds of the Lobi-

ferus-shales seen consist of thin black "wafer" shales crowded with *Climacograptus normalis*, and interbedded with grits.

In a lane near Nitsjo, the red beds of the Trinucleus-shales are succeeded by a thin bed of white gritty oolitic limestone, above which Törnqvist has seen the Lobiferus-shales; but these are no longer exposed. This limestone here represents the base of the Silurian, and is, as will be described hereafter, similar to other beds occupying the same position in other areas of Sweden.

The Lobiferus-beds of Dalecarlia indicate somewhat shallower-water conditions than do their graptoliferous equivalents in other countries. They are grey, often gritty shales, containing Graptolites, sometimes along with higher organisms, as at Kallholn.

The Retiolites-shales are more flaggy than the Lobiferus-shales. They are usually light grey, sometimes green or red, and have interbedded calcareous bands and nodules. They are well seen at Stygforsen near Boda, where they are faulted against the "Slipsandsten."

Leptæna-Limestone.—This is the most puzzling of all the Dalecarlian formations. It consists principally of a coarsely crystalline white limestone, with interbedded shaly partings. Gritty beds occur in places, as near Rättvik, on Lake Siljan. The lower part is formed of thin-bedded shaly green limestones as seen at Arfvet and Boda. The fauna would at first sight seem to indicate a position below the Retiolites-beds, and even below the Lobiferus-beds. The limestone is hardly ever seen in its true place, occurring usually as a boss in the middle of a valley, with no rocks exposed on either side. In many cases its present position is due to faulting, and perhaps in some cases, as suggested by Dr. Törnqvist, to transportation by ice during the glacial period. A summary of the evidence for placing it above the Retiolites-beds may be given :—

(i.) It cannot be below the Trinucleus-shales, as a continuous sequence is often exposed below these beds.

(ii.) It cannot be between the Trinucleus-shales and the Lobiferus-shales; for in many sections these beds are seen very near together, with no room between for the Leptæna-limestone, which is many hundred feet in thickness, and at Nitsjö the interval is occupied by a thin band of limestone, only a foot or two in thickness; the Leptæna-limestone of Boda also contains fragments of other rock, including a green grit, probably of Precambrian age, and also of *shales containing Graptolites characteristic of the Lobiferus-beds.* These fragments are often of great size, some being several feet in diameter, and quite angular; and they may have been brought from the north by floating ice.

(iii.) The Leptæna-limestone cannot occur between the Lobiferus- and Retiolites-shales, as the former pass gradually into the latter, as seen at Kallholn. If the fragments of Lobiferus-beds included in the Leptæna-limestone be supposed to come from the north, this will account for the absence of fragments of Retiolites-shales in the same beds; for these were not deposited further north, as will be seen in the sequel.

(iv) The occurrence of the Leptæna-limestone above the Retiolites-shales is borne out by its position at Kallholn, where the following is the apparent section in ascending order:—

1. Lobiferus-beds, seen in a stream-section.
2. Passage-beds between the Lobiferus-beds and Retiolites-shales, containing an intermixture of the faunas, on the same slabs of stone, in a well-section.
3. Retiolites-beds, in another well-section.
4. Leptæna-limestone in a small quarry on hill-side.

This is the only locality in Dalecarlia where the Leptæna-limestone does not show indications of having been disturbed.

Again the grey shaly base of the limestone, as seen at Arfvet and Boda, presents just such an appearance as might be expected in beds of passage between the Retiolites-shales and the Leptæna-limestone itself.

No newer beds of Silurian age are founed in Dalecarlia.

II. *Ostrogothia and Westrogothia.*—In Ostrogothia the Cambrian and Silurian rocks are seen in a few exposures on Lake Wetter and along the banks of the Gotha Canal. In Westrogothia they occur well exposed along the peculiar terraced hills so characteristic of that province, the most celebrated of which is Kinnekulle. This region has been admirably described by Dr. Linnarsson in many memoirs. As these have made the stratigraphy of this region familiar to all students of the lower palæozoic rocks, it is unnecessary to describe the beds in detail, and I shall therefore confine myself to observations of the beds at the top of the Cambrian system and the base of the Silurian, as a study of these beds throws considerable light upon the classification of these deposits. I have studied the boundary between the two systems on Lake Wetter at Råsnäset, in the neighbourhood of Motala, and near Falköping, in the hills of Mösseberg and Ålleberg. In all these localities the top beds of the Trinucleus-shales are red shales, often calcareous, as in Dalecarlia. At Råsnäset these beds are succeeded conformably by green shales with thin bands of green nodular gritty limestone, and containing fossils, especially Trilobites, such as *Calymene*, *Encrinurus*, and *Sphærexochus*; these beds are about twenty feet thick. Resting upon them, somewhat irregularly, is a bed of greenish limestone of a gritty character, containing much pyrites and oolitic in places; except in colour this bed in every particular resembles the band of limestone at Nitsjö, in Dalecarlia, and, like that bed, is immediately succeeded by the Lobiferus-shales, which are here of a wafery character and crowded with Graptolites.

In the hills near Falköping the red Trinucleus-shales are succeeded by green shales similar to those above the Trinucleus-shales of Råsnäset. These are overlain conformably by blue flaggy beds of considerable thickness, passing into gritty beds at the summit. These beds appear to contain few fossils; but I obtained a *Trinucleus* from the grits. Resting upon this series is a horny grey pyritous limestone, succeeded by coral-bearing limestones, and these by calcareous grits, which are very fossiliferous. These latter are the

zone of *Phacops mucronatus*, Brongn., and pass gradually into the ordinary wafery Lobiferus-shales, the Passage-beds containing *Climacograptus normalis* mixed with higher organisms. The Lobiferus-beds are succeeded in Westrogothia by the Retiolites-shales, well seen on Kinnekulle; and on the highest terrace below the igneous rock of the summit of that hill, near the hamlet of Kullatorp, I found loose blocks of gritty shale with *Monograptus colonus*, Barr., indicating the existence in Westrogothia of a higher horizon than the Retiolites-shales.

Near the same hamlet, below the Retiolites-shales, there are some green shales in which I could find no fossils; and below these is swampy ground running along the line of strike, indicating probably the position of the Lobiferus-beds.

III. *Christiania*.—The geology in the neighbourhood of the capital of Norway, so admirably worked out by Prof. Kjerulf, has been illustrated by him, in a form well suited for the requirements of a visitor, in his 'Veiviser.' I am much indebted to Mr. Brögger for taking me to some of the principal sections around Christiania. I would here again refer more particularly to the higher Cambrian beds and those at the base of the Silurian; for the lower Cambrian beds are very similar, generally speaking, to those of Westrogothia, and have been well described by Brögger and others. A section of the higher beds is given in 'Siluria,' p. 349, as seen in the islands of Ormö and Malmö in the Christiania fjord. The lowest beds seen in Ormö (7 of Murchison, Étage 4 Kjerulf) are limestones of Bala age with *Chasmops* &c. These are succeeded unconformably by a conglomerate (8 Murch., Ét. 5 Kjer.) consisting of a calcareous gritty matrix, with many pebbles, some as large as a hen's egg. Following upon this are olive-grey shales (9 Murch., 5 β Kjer.) with interbedded limestone, containing many fossils, a list of which is given in the 'Veiviser;' and in this bed Mr. Brögger and myself found *Climacograptus normalis*. *Nidulites favus* and *Stricklandinia lens* occur in the upper part of this group, which is overlain by nodular grey limestone (9 b Murch., Ét. 6 Kjer.) containing *Pentamerus oblongus*, and this by (10 Murch., Ét. 6 Kjer.) limestone with many corals. Formation no. 11 of Murchison (Ét. 7 Kjer. in part) consists of brown sandy shales and calcareous bands containing many crinoid stems, and succeeded by blue flaggy shales (13 Murch., Ét. 8 Kjer. in part) with *Monograptus priodon*, *M. Halli*?, and higher organisms. The highest beds in Malmö (14 Murch., Ét 6 Kjer. in part) are grey limestones with *Euomphalus funatus*, *E. sculptus*, *Pterinea retroflexa*, &c., which Murchison correlates with the Ludlow; but they are probably in reality Wenlock.

IV. *Scania* (*Skåne*).—This province, again, has been especially elucidated by Dr. Linnarsson, whose discoveries have been made familiar to us by the writings of Prof. Lapworth (Cf. Geol. Mag. dec. ii. vol. vii. Jan. and Feb. 1880), where a list of the Scanian formations is given. I was enabled, by the kindness of Prof. Lundgren, to study the collections in the Lund University Museum, and was accompanied in the field by Dr. Tullberg.

The sequence above the Trinucleus-shales is strikingly similar to that of Westrogothia. As in that province, so here, those shales are overlain by greenish shales and calcareous beds with *Sphærexochus*, &c.; and above these are blue flaggy beds with *Phacops eucentra*, Ang., which was described and figured from specimens out of these beds at Röstånga. The same species occurs in similar beds at Borenshult, in Ostrogothia. These blue flags, I am informed by Dr. Tullberg, are succeeded by a band of limestone, one or two feet in thickness, above which are the Lobiferus-shales. The Lobiferus-beds are overlain by Retiolites-shales, and these by beds containing *Monograptus colonus*, *M. bohemicus*, *Cardiola interrupta*, &c. They are greyish-green gritty shales, with large lenticular masses of limestone, as at Bjersjölagård, which contain characteristic Wenlock fossils. This is succeeded by grey gritty shales, lithologically continuous with the Cardiola-beds, but poorly fossiliferous; and above these come green shales and sandstones, yellow at Bjersjölagård, red at Ramsåsa, with characteristic Ludlow fossils.

V. *Baltic Islands.—Gothland.* In a hasty examination of the principal sections of this island I could not see sufficient evidence to prove that there are two distinct masses of limestone, representing Wenlock and Aymestry limestones respectively, as described by Murchison. The dip is so slight that it is impossible to tell whether, the Visby limestone dips under that of Klinte; and the occurrence of somewhat different forms of life may be merely due to the difference of lithological character, as is so well seen in the case of E. e. 2 in Bohemia. *Monograptus priodon*, recorded by Dr. Linnarsson (Öfv. af K. Vet.-Akad. Förh. 1879, no. 5) in the Klinte group, would seem, as stated by Prof. Lapworth (Geol. Mag. *loc. cit.*), to bear out this view; for he says that he has never been able to detect any fragment of *M. priodon* in the lower Ludlow rocks. I believe Prof. Lindström also differs from Sir R. Murchison in his explanation of this section.

Bornholm.—By the kindness of Prof. Johnstrup, I was enabled to examine the collection made by him in this island, and preserved in the Copenhagen University Museum. The geology of the island has been described by him (Johnstrup, Oversigt over de Pal. Dannelser paa Bornholm). The Ceratopyge-limestone and Phyllograptus-shales are described as missing; so that there is an overlap, and the Alum-shales are succeeded (apparently conformably) by the Orthoceras-limestone. The Trinucleus-shales are noteworthy, as they are calcareous ashy beds, much resembling the more shaly parts of the Coniston Limestone of England. The Lobiferus-beds and Retiolites-shales are described together, and a mixed list given; but they occur apart.

The Retiolites-beds contain:—

Monograptus priodon, *Bronn.*
—— vomerinus, *Nich.*
—— spiralis, *Gein.*
Retiolites Geinitzianus, *Barr.*
Cyrtograptus Murchisoni, *Carr.*
Ceratiocaris Murchisoni ?
Aptychopsis primum, *Barr.*
Modiolopsis.
Orthoceras primævum.
—— laqueatum ?
—— subundulatum.
—— tenuicinctum.

§ 3. *Comparison of the Strata with British and Bohemian Deposits.*

The Scandinavian strata have been correlated with those of Britain and Bohemia by various authors, notably by Dr. Linnarsson (*cf.* Geol. Mag. 1876, p. 245, and 1878, p. 278; Öfv. af K. Vet.-Akad. Förh. 1873, no. 5; and Lapworth, Geol. Mag. 1880, p. 29), by Dr. Törnqvist (Öfv. af K. Vet.-Akad. Förh. 1879, no. 2, p. 63), by Prof. Lapworth (Ann. and Mag. Nat. Hist. ser. 5, vol. iii.), and by Dr. Tullberg (Geol. Fören. i Stockh. Förh. 1880, no. 59, Bd. v. no. 3). I would here consider more fully the beds at the top of the Cambrian and the base of the Silurian systems. Passing over the representatives of the Harlech, Menevian, and Lingula-formations, and commencing with the Ceratopyge-limestone, we find this correlated by Dr. Linnarsson with the Tremadoc slates of England (Kongl. Vet.-Akad. Förh. 1869). The Orthoceras-limestone is underlain by shales with *Phyllograptus* in Westrogothia, and overlain by Phyllograptus-shales in Scania, as described by Dr. Linnarsson, whilst the genus is found in shales intercalated with the Orthoceras-limestone of Dalecarlia (Törnqvist, Geol. Fören. i Stockh. Förh. 1879, no. 56, Bd. iv. no. 14, p. 446); so that Törnqvist (Öfv. af K. Vet.-Akad. Förh. 1879, no 2, p. 69) correlates this limestone with the Arenig group of Britain. The limestone itself seems to have been a shallow-water deposit; and its fauna is interesting as bearing on the subject of migrations. The deep-water fauna, as seen in the thin band of red shales at Skattungbyn in Dalecarlia, and in the Phyllograptus-shales, corresponds with that of D. d. 1 γ of Bohemia, and of the Arenig of Britain.

The succeeding Graptolitic shales of Scania have been correlated by Prof. Lapworth and Dr. Tullberg (*loc. cit.*), zone for zone, with the corresponding beds of the south of Scotland; but these Graptolitic shales are replaced by shallower-water deposits in Westrogothia, Dalecarlia, and the neighbourhood of Christiania.

In Dalecarlia, as in Bohemia, above the Arenig beds are two series of shallow-water deposits, and two of deeper water. The Cystidean limestone of Dalecarlia, containing Cystideans of the *aurantium*-type, along with *Chasmops, Stygina*, &c., is supposed by Törnqvist to be the equivalent of the Lower Bala of Britain; and it corresponds in position with D. 2 of Bohemia, although there is no resemblance, either lithological or palæontological, between the two deposits. The next succeeding formation, however, the green shales of Kärgårde and Fjecka do somewhat resemble the shales D. 3 of Bohemia; they seem to be more allied to the Cystidean limestone than to the Trinucleus-shales, and probably are also of Lower Bala age. The hard limestone of Fjecka lying below the Trinucleus-shales may be the same as the band D. 4 of Bohemia, as the succeeding Trinucleus-shales, which are similar in character in various parts of Sweden, have long since been correlated by Dr. Linnarsson with band D. 5 of Bohemia; I should, however, correlate them only with the lower part of that band, viz. the Kralův Dvůr shales. Not only are the Trilobites identical in genera, but the species are

either the same or very closely allied, as shown by Linnarsson in his description of the geology of Westrogothia ; moreover the characteristic Graptolite of the Swedish Trinucleus-shales, as of the Kralův Dvůr shales, is *Dicellograptus anceps*.

The Beyrichia-limestone of Westrogothia, which contains *Chasmops*, perhaps continued forming after the Cystidean limestone of Dalecarlia had ceased to be deposited, as the former is immediately surmounted by the Trinucleus-shales.

In the neighbourhood of Christiania there are no Trinucleus-shales, but the highest Cambrian beds consist of limestones.

The highest beds of the Cambrian series occur in Ostrogothia, Westrogothia, and Scania. They are the green Sphærexochus-shales, the blue shales of Mösseberg and Ålleberg in Westrogothia, of Borenshult in Ostrogothia, and of Röstånga in Scania, and the gritty beds of Mösseberg with *Trinucleus*. These beds are in lithological character quite similar to the Ashgill shales of the Lake-district, and their faunas are similar. Common to the two are *Turrilepas* sp., *Beyrichia* n. sp., *Phacops eucentra*, Ang.*, *Cybele*, *Orthis testudinaria*, *Holopea concinna*.

Dr. Törnqvist identified the Brachiopod-beds of Sweden with the Ashgill shales, but included beds which I would refer to the base of the Silurian system.

The beds with *Phacops eucentra* are probably the equivalents of the Kosov grits of D. 5 in Bohemia.

We are now in a position to consider the break between the Cambrian and Silurian systems, as marked in Scandinavia.

The highest Cambrian beds of Sweden are the *Phacops-eucentra* group, as seen in Mösseberg &c. They are divisible into three groups—an upper gritty one, a middle one of blue flags, and the lower green Sphærexochus-shales. In Ostrogothia, at Råsnäset, the two upper groups have disappeared, and the base of the Silurian reposes upon the Sphærexochus-shales. In Dalecarlia there is no representative of the *Phacops-eucentra* beds, and the Trinucleus-shales are immediately succeeded by Silurian beds. At Christiania the Trinucleus-shales themselves are absent, and the Silurian basement rocks repose upon limestones with *Chasmops*, which may, however, partly represent Trinucleus-shales. Where the junction between the Silurian and Cambrian is seen, it is usually found to be an uneven one, even where the highest Cambrian beds are seen near Falköping; so that the whole evidence is in favour of an unconformity.

The highest beds of the Cambrian are laminated false-bedded grits, showing shallow-water conditions. The physical break is accompanied by a palæontological one, as admitted by Swedish palæontologists.

* The *Phacops eucentra* of Angelin was founded on specimens from the blue shales of Röstånga ; it is in every respect identical with the *Phacops* of the Ashgill shales (cf. Q. J. G. S. 1878. p. 884), which I referred to a variety of *P. mucronatus*, stating that it would have to be ultimately separated. The true *P. mucronatus* occurs in the upper part of the Brachiopod-beds of Westrogothia.

The basement beds of the Silurian everywhere indicate that they were deposited in shallow water. Where they consist of thin beds of limestone they are immediately succeeded by the Lobiferus-shales, as in Dalecarlia, Ostrogothia, and Scania. In Westrogothia the upper part of the Brachiopod-beds consists of a series of calcareous grits, with fossils of May-Hill facies, the characteristic fossil being *Phacops mucronatus.* The upper part of these beds contains an admixture of the Brachiopod-bed fauna with Graptolites characteristic of the Lobiferus-shales. At Christiania the basement-conglomerate of the Silurian is succeeded by shales with a characteristic May-Hill fauna, such as *Nidulites favus, Stricklandinia lirata, Phacops mucronatus,* and *Ph. elegans,* Bœck and Sars. With these fossils, as before mentioned, is *Climacograptus normalis.* These beds, then, appear to be the representatives of the Birkhill shales, as are perhaps in part the succeeding *Pentamerus-* and coral-limestones. The green Encrinital shales above this probably represent the Tarannon shales, as they are in turn immediately overlain by blue flags with *Monograptus priodon,* &c. The May-Hill beds of Scandinavia seem to have been deposited for the most part in shallower water than the corresponding Birkhill shales of Britain, but in deeper water than the beds of the typical Llandovery area; they are therefore of great value, as presenting us with a type intermediate in character between our two widely different Llandovery types. The occurrence of a *Remopleurides* in these beds at Christiania is noteworthy, as this genus occurs in still higher beds in Dalecarlia. *Trinucleus Wahlenbergi* is recorded by Prof. Kjerulf as occurring in these beds; it is possible that this may be a *remanié* fossil, derived from Cambrian beds.

It was before suggested that certain green beds at Kinnekulle in Westrogothia might be the representatives of the Tarannon shales. In Dalecarlia there is no similar lithological band, and the Lobiferus-shales pass into the Retiolites-shales. These passage-beds are undoubtedly of Tarannon age, as they contain an admixture of the species of the two faunas, as discovered by Dr. Törnqvist.

I have since found that a zone at Kuchelbad, Bohemia, yields a similar admixture, and occupies a position corresponding with that of the zone at Kallholn.

The fauna of the Retiolites-beds of Scandinavia is quite similar to that of Bohemia and Britain; so that there is no doubt whatever about the correlation of these beds.

Above the Retiolites-beds of Dalecarlia is the Leptæna-limestone, to the fauna of which I shall refer more particularly when considering migrations. It may possibly be in part the equivalent of the upper part of the Brathay flags of the Lake-district, or may be still higher: at any rate it must be Wenlock, although it has a considerable mixture of Llandovery forms.

It is doubtful whether any beds occur at a higher horizon than the Retiolites-beds of Westrogothia; but I referred before to the possible occurrence of beds with *Monograptus colonus* at Kinnekulle.

In Scania, on the other hand, there are several formations above the Retiolites-beds.

The *Cardiola interrupta*-beds have precisely the same characters and fauna as the Coldwell beds of the Lake-district, and occur in the same relative position.

The grey gritty beds of Bjersjölagård are probably on the horizon of the Coniston grits, and perhaps also of the lower portion of the Bannisdale slates. Dr. Tullberg correlates these and the underlying Cardiola-beds with the Lower Ludlow; but they are in the position of, and have the same fauna as, true Wenlock beds.

The green shales and yellow sandstones of Bjersjölagård and the red sandstones of Ramsåsa, on the other hand, have a true Ludlow fauna.

I have already stated that the highest beds of Malmö, near Christiania, with *Pterinea retroflexa* &c., are really Wenlock.

The following table is the summary of the correlation of the principal beds of Scandinavia, Bohemia, and Britain, as described in the preceding account:—

Table of Equivalent Strata in Scandinavia, Bohemia, and Britain.

Scandinavia.	Bohemia.	Britain.	
Sandstones of Ramsåsa and Bjersjölagård.	F, G.	Ludlow.	Silurian.
Cardiola-beds. Cyrtograptus- and Retiolites-shales.	E. e. 2. E. e. 1 in part.	Wenlock.	Silurian.
Lobiferus-shales. Upper part of Brachiopod-beds.	E. e. 1 in part.	May Hill.	Silurian.
Lower part of Brachiopod-beds.	D. d. 5 (Kosov Grits).	Upper Bala.	Cambrian.
Trinucleus-shales. Beyrichia-limestone.	D. d. 5 (Kralův-Dvůr Shales). D. d. 4.	Middle Bala.	Cambrian.
Kärgårde Shales. Cystidean Limestone.	D. d. 3. D. d. 2.	Lower Bala.	Cambrian.
Orthoceras-limestone. Phyllograptus-shales.	D. d. 1 γ	Arenig.	Cambrian.
Ceratopyge-limestone.	D. d. 1 β.	Tremadoc.	Cambrian.
Olenus-beds.	D. d. 1 α and unconformity.	Lingula-flags.	Cambrian.
Paradoxides-beds.	C.	Menevian.	Cambrian.
Fucoid Sandstone. Eophyton-sandstone.	B in part.	Harlech.	Cambrian.

§ 4. *Migrations of the Faunas.*

The migrations of the Swedish faunas may be studied in two ways: —first, by noticing the occurrence, in two beds of different age, of

forms which do not occur in the intermediate beds; secondly, by tracing the lateral movements of the forms of life, and discovering them in earlier beds in one locality than in another. The first method is particularly applicable to beds deposited in deep water, the second to those deposited in water nearer the sea-margin.

In the first place, which beds were deposited in deep water, and which near the sea-margin? I have previously given reasons for supposing that the black shales of the Cambrian and Silurian systems were deposited in comparatively deep water, from the evidence derived from the eyes of the Trilobites contained in them. *Remopleurides* is usually characterized by very large eyes. In Jemtland, however, Dr. Linnarsson has found one in calcareous beds, but it has *small* eyes, *R. microphthalmus*, Linnars. (Geol. Fören. i Stockh. Förh. 1879, p. 246). These black sediments are found also over a very large area; so that they must in some cases at least have been deposited several hundred miles from land. How are we to account for the fact that the open oceans of Cambrian and Silurian times received these mechanical deposits, whilst the open seas of our own times have deposits of ooze being formed in them?

On examining the list of stations of the 'Challenger' voyage given by Sir Wyville Thomson (Atlantic, vol. i. p. 93), it will be remarked at once that in very few places is mechanical deposit formed at a greater distance than 100 miles from land, nearly all the deposits at this distance being grey or red ooze, except volcanic deposits, such as may be formed by submarine volcanoes. Off Cape San Antonio, however, near Bahia, mud is found at considerable distances over 100 miles from land: thus at station 127 mud occurs at a distance of 120 miles, at station 124 at 251 miles, and at station 120 at 360 miles from this cape; so that there is a continuous deposit of mud being formed here to a distance of between three and four hundred miles from land. The rock along this coast is gneiss (cf. Darwin, Geol. Obs. p. 422); so that the great distance to which mud is carried here, seems to be due to the fact that *this mud is directly derived from the decomposition of felspar of metamorphic rocks*, and not indirectly by the denudation of other unaltered sedimentary rocks; and it is therefore in an extremely fine state of division. But the land which bounded the Cambrian and Silurian oceans must have been made up of such felspathic rocks; for we find that the greater part of the Precambrian rocks had undergone extensive regional metamorphism before the deposition of the earliest Cambrian rocks, and this seems to account for the presence of fine deposits of mechanical origin over a very large area in Cambrian and Silurian times.

In a former paper (Q. J. G. S. Nov. 1880, p. 606) I referred to the occurrence of migrations in Bohemia, treated of by M Barrande (Déf. des Colonies, pt. iii.), as evidenced by the occurrence of deep-water forms in D. d. 1, d. 3, and d. 5, which do not occur in D. d. 2 and d. 4. A precisely analogous case is found in Sweden. The red shale band in the Orthoceras-limestone of Skaltungbyn (Dalecarlia), the grey calcareous shales of Fjecka and Kärgårde, and the

Trinucleus-shales, contain *Turrilepas*, *Trinucleus*, and *Remopleurides*, whilst the first and last also contain *Agnostus trinodus*. These are absent, or occur very rarely in the intermediate Cystidean limestone and in the hard limestones.

But the shallower-water beds are more interesting as illustrating migrations.

In a paper by Dr. Hicks (Q. J. G. S. Nov. 1875, p. 557), the author concludes that a Precambrian continent extended over Europe, with a general inclination to the south-west, and that as this continent was gradually submerged, migrations of marine faunas took place from the south-west, where ocean areas prevailed.

The deep-water faunas certainly bear out this view; but the migration of shallow-water forms seems to have taken place along the coast-lines, and to have proceeded much more slowly than that of the deep-water forms; so that it becomes much more difficult to correlate shallow-water deposits by their faunas than to correlate those formed in deep water. This is easily accounted for, as the deep-water deposits were of a uniform character over large areas, so that animals could migrate widely, and still meet with suitable conditions, whereas the inhabitants of the shallower seas would require some time, and also undergo considerable change, whilst passing from one kind of sediment to another.

Dr. Törnqvist (Öfv. af Kongl. V.-Akad. Förh. 1879, No. 2, p. 70) considers that during Cambrian and Silurian times, Sweden alternately underwent an invasion of shallow-water forms from Russia, and of deep-water forms from Britain. Dr. Hicks's opinion of the direction taken by the deep-water faunas seems, however, more correct, whilst the direction taken by the shallow-water forms seems to have varied considerably, according as they were influenced by widespread movements or by more local ones.

In later Cambrian times, the shallow-water forms seem to have moved along the coast-line in a general W.S.W. direction from Russia to Britain. The Orthoceras-limestone of Sweden, correlated with the Arenig, contains large *Asaphi*, which do not occur in Britain until Lower-Bala times.

The Cystidean limestone contains Cystideans, such as *Echinosphærites aurantium*, and *Phacopes* of the subgenus *Chasmops*, which are found in somewhat earlier beds in Russia, but first occur in Wales in Middle-Bala beds, whilst, as I have before pointed out (Q. J. G. S. May 1880, p. 279), the Cystideans did not reach the Lake-district until Upper-Bala times. These migrations seem to be simply due to the remoteness of Britain from land in Arenig and Lower-Bala times; for there are no shallow-water forms of Arenig age, and very few of Lower-Bala age, in the southern parts of Britain.

In the earlier Silurian times, however, a change seems to have taken place in the direction of migration, owing to the fact that widespread upheaval was accompanied by a greater local upheaval in Britain, so that this became a centre of dispersal in May-Hill times, from which shallow-water forms migrated. The coast-line

in fact, instead of running in a N.N.W. and E.S.E. direction, seems to have run more W.S.W. and E.N.E.; for we find many shallow-water deposits in Britain at this period, but deep ones in the central Swedish areas. The May-Hill fauna, as it occurs in Wales, seems to have spread as far as Christiania and Westrogothia (Brachiopod-beds) in May-Hill times, but to have been there stopped by deep-water from reaching Dalecarlia, where the Lobiferus-beds occur. Deep water prevailed also in this area during the accumulation of the succeeding Retiolites-beds; but the overlying Leptæna-limestone has a decided admixture of May-Hill forms such as *Sphærexochus angustifrons*, *Remopleurides*, *Meristella crassa*, *Stricklandinia*, *Orthisina adscendens*, *Leptæna quinquecostata*, *Macrochilus*, &c. (cf. Törnqvist, Öfv. af Kongl. Vet.-Akad. Förh. 1879, no. 2, p. 76); so that one would expect to find shallow-water deposits of Retiolites-shale age further north than Dalecarlia, in order to allow of the migration into Dalecarlia of these forms. Such shallow-water deposits occur in Jemtland (Linnarsson, Geol. För. i Stockh. Förh. 1879). Mingled with the forms enumerated are others which seem to have come from Russia, as *Illænus Volborthi*, and others, again, of characteristic Wenlock type, which may have migrated from the Gothland area. Besides these, there are several forms (such as *Isocolus Sjögreni*) which are peculiar to the bed. This explanation of the occurrence of May-Hill forms in the Leptæna-limestone obviates all the difficulties which have been raised concerning its age.

§ 5. *Summary.*

The classification of Prof. Sedgwick is quite applicable to the older palæozoic rocks of Sweden.

The boundary at the base of the equivalents of the May-Hill beds is marked by three distinct kinds of events: first, there is a physical break, as indicated by the absence of several beds at the summit of the Cambrian in various localities, and by the occurrence of conglomeratic beds at the base of the Silurian, resting unevenly upon the older deposits; secondly, there is a palæontological break, which is more especially marked in the case of the deep-water beds; for although the various deep-water beds of Cambrian times have often species in common, or closely allied representative species, as have those of the Silurian also, there are very few common to the two systems; thirdly, the trend of the coast-line in early Silurian times seems to have been totally different from that which existed in late Cambrian times, thus giving rise to a considerable difference in the direction of migration of the shallow-water faunas of the two systems.

Is there any other break of equal importance to this one in Scandinavia? Several authors have drawn a boundary at the base of the Ceratopyge-limestone, on palæontological grounds: there is no physical break there; and the value of the palæontological break may be estimated from the following remark of Dr. Törnqvist (Öfv. af K. Vet.-Akad. Förh. 1879, no. 2, p. 66):—"In Scandinavia

the resemblance between the fauna of the Ceratopyge-limestone and that of the underlying beds is so great, that we have much difficulty in drawing a boundary between the primordial fauna and that which is usually styled Lower Silurian."

DISCUSSION.

Dr. HICKS remarked upon the importance of the paper; it would be a welcome addition to our knowledge of this region. The position of the break at the base of the Silurian beds (Upper Silurian of Murchison), showing great and widespread movement extending into the Scandinavian area, was very interesting. The break does not, however, exist everywhere, and therefore does not denote such important earth-movements as took place prior to the Cambrian or at the close of the Palæozoic. He was glad to find that Mr. Marr agreed in the main with the views he had expressed about the physical geography of the Cambrian and Silurian periods and the lines of migration.

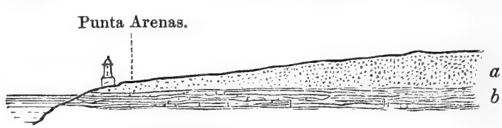
33. *On the* Geology *of a Part of* Costa Rica. By George Attwood, Esq., F.G.S., F.C.S., Assoc. Mem. Inst. C.E., Mem. Am. Inst. M.E., &c. *With an* Appendix *by* W. H. Hudleston, Esq., M.A., F.G.S., F.C.S., &c. (Read May 24, 1882.)

[Plate XII.]

Having spent a portion of last winter in the mountains of Costa Rica, I was enabled to collect some interesting rocks, and also to compile a map with a section of the ground over which I travelled, (Pl. XII.); and I now beg to present the same to the Society.

The starting-point of my travels was the town of Punta Arenas, situated on the Bay of Nicoya, Republic of Costa Rica, Central America. The town is built near the extreme end of a peninsula which reaches out into the Bay of Nicoya (fig. 1). The base of the peninsula is a calcareous sandstone (fig. 2), containing a large amount of carbonate of lime and some mica-grains. The sandstone is nearly horizontal; and where it has been exposed by the action of the sea near the coast it shows evidence of having been recently attacked by boring mollusca (*Lithodomi*). The peninsula, which is almost eight miles in length, and from half a mile to two miles in width, is covered with a dark shining sand, which varies from 50 to 300 feet in thickness and extends over nearly its entire area. The sand is fine, the largest grains or crystals not exceeding $\frac{1}{10}$ inch in diameter, while the average diameter is about $\frac{1}{50}$ inch. When examined under the microscope, it contains about 25 per cent. of magnetite and about 25 per cent. of quartz-grains, the remainder being made up of felspar and probably augite and their decomposition-products.

Fig. 1.—*Longitudinal Section of the Peninsula of Punta Arenas.*



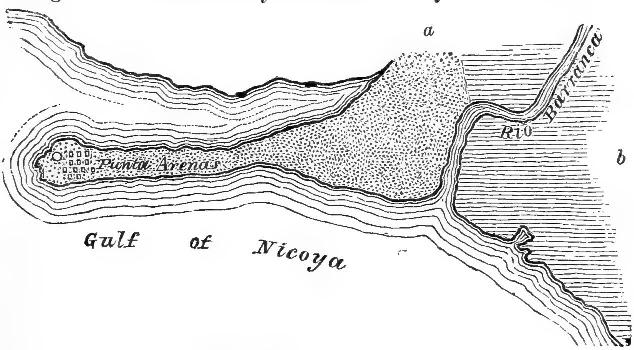
a. Fine Sand.
b. Calcareous Sandstone.

The sand deposit appears to have originated from the material brought down by the overflow of the north-west bank of the Rio Barranca. The Rio Barranca is a swift river, whose source is in the hills called Cerro el Tigre, distant in a northerly direction about thirty-five miles, and at an elevation of over 3000 feet above the sea-level. There is no evidence of a late overflow; and, from the high bank of sand left by the original overflow, there is little probability of such a thing occurring again.

The gulf of Nicoya is being rapidly filled up to the north-west of

the peninsula of Punta Arenas, owing to the strong south-west current in the Bay of Nicoya bringing all the sands from the rivers Rio Grande, Jesus Maria, and Rio Barranca, all of which rivers bring down with them the decomposed igneous rocks from the Costa-Rican Andes and its spurs. However, the peninsula is being cut away in the south by the current, as is proved by the trees lately overturned.

Fig. 2.—*Sketch Plan of the Peninsula of Punta Arenas.*



a. Fine Sand.
b. Consolidated Volcanic Ash.

On crossing the Rio Barranca, and proceeding as far as the volcanoes of Irazu and Turrialba (see Map, Pl. XII.), and then on to the old Indian settlement called Orosi, the rocks met with present a great similarity in their structure. The general rock of the district shows itself on both sides of the Rio Barranca after leaving the sands of the Punta-Arenas peninsula, and continues for about fifty miles in an easterly direction towards Cartago, the ancient capital of the country, although on the Aguacate range of mountains rocks of volcanic origin make their appearance. The same general rock is also found beyond Cartago, in the direction of Orosi. The rock is fine-grained, presenting a greenish appearance; and wherever it is not weathered it is tough and difficult to quarry. It has a granular base, and contains crystals of triclinic felspar with augite, also small quantities of magnetite; specimens obtained on the mountain-range of Aguacate, near the gold- and silver-mines, show specks of pyrites, and may be regarded as a consolidated volcanic ash.

The specimen collected near the Rio Barranca was more coarsely fragmental than those collected in the mountains further in the interior, and the felspars were more weathered (Appendix, No. 8, p. 339).

On the south-east side of the Rio Barranca, before the village of Esparto is reached, large boulders of a black rock are frequently seen. They were examined, but were evidently strangers to this particular locality. From Esparto to San Mateo the country is rugged and mountainous, the surface being cut up by a continuous

succession of ravines and gorges. The country rock is the same as near the Rio Barranca; and on the mountain-slopes and in the beds of the streams boulders of the same black rock are found. San Mateo is situated about 1050 feet above the sea-level, with mountain-peaks on all sides. The black boulder stones were frequently examined, and a typical piece selected for examination (Appendix, No. 3, p. 337).

This boulder-rock is very dark, approaching black, with a compact ground-mass; it is extremely hard, and in places presents a vitreous appearance. It contains triclinic felspar, augite crystals, magnetite, and small specks of pyrites, and may be classed as a variety of the andesites, under the head of augite-andesite.

From San Mateo the ground ascends rapidly as the important mountain-chain called Aguacate is approached. In the Aguacate Mountains are found the best gold- and silver-mines now known in Costa Rica. The mountains are a branch of the Costa-Rica Andes; and they have a general north-westerly direction for twenty miles. Some of the peaks are over 1400 feet high.

The principal mines now being worked belong to the Aguacate, Sacra Familia, and Quebrada Honda Companies; but many others are being tried. Although the veins are numerous, they have a general strike north 35° east, with an average dip of 80° to the north-west, and run parallel to a great extent (fig. 3). The veins can be traced for considerable distances.

The Oreamunas-San Rafael-Los Castros lode (belonging to the Aguacate Company) has been followed for four miles in length, and is about 15 feet in width. The filling of the fissures which constitute the lodes consists largely of quartz, occasionally mixed with calcite and much argillaceous matter, evidently the result of the decomposition of the felspar in the adjacent rocks.

The gold is generally disseminated in minute flaky or filiform particles through the veinstone; it contains a variable quantity of silver, and has a pale yellow to yellowish-white colour. Occasionally some flattened and rounded grains are found. The average fineness of the gold from the Aguacate mines, which has been minted at San José (the present capital of Costa Rica), according to the statement of Mr. W. Whitting (Director of the Mint) is

620=62 per cent gold,
380=38 ,, ,, silver,

and is what is called "electrum."

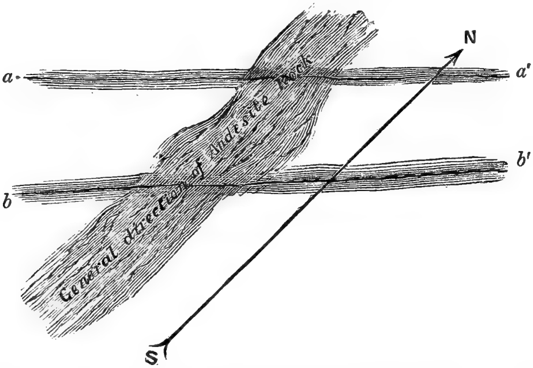
The principal minerals in the vein-matter with which the gold and silver are more or less associated, are arsenical pyrites, iron- and copper-pyrites, galena, and a little zinc-blende. The arsenical pyrites predominates; and the silica, besides appearing as hyalite and chalcedony, is sometimes found in the form of a dry crystalline powder resembling pulverized white sugar. The latter is most frequent in the small vein-feeders, or stringers, which connect with the mother veins.

A large amount of gold and silver has been extracted from the

Aguacate mines by very crude appliances since they were first discovered in 1822; and the value may be estimated at £1,200,000.

On the Aguacate Mountains volcanic rock-masses were observed on the hill-tops, on the sides, and in the ravines. They have a general north-and-south direction, as may be inferred from their strike. In the mine-workings, however, which have reached a depth of 400 feet vertical, although several miles of subterranean galleries were explored, no evidence of any eruptive rock-masses cutting the veins was discovered, or of their disturbing the same. Numerous galleries which have been run outside the veins prove, in many cases, the existence of the two different rocks—the country rock (or consolidated ash) and the augite-andesite, which are often in contact (fig. 4).

Fig. 3.—*Directions of Lodes in the Aguacate Mines.*



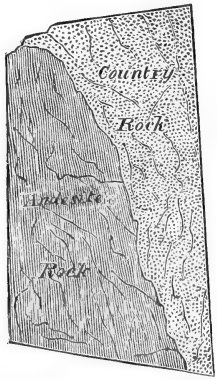
a, *a'*. Strike of the Oreamunos-San Rafael-Los Castros lode, N. 41° 30′ E.
b, *b'*. Strike of the San Miguel lode, N. 37° E.

This latter rock presents a great resemblance to the black-looking boulder-stones found on the hill-sides near the road on the way from Esparta; and the result of a microscopical examination of rocks found near the surface *in situ*, and of others obtained 400 feet below the surface in one of the Aguacate Company's galleries called the San Rafael Level (Appendix, No. 4, p. 337), prove them to be almost identical. They have a compact base, are of a brownish-black colour, contain triclinic felspar, augite, magnetite, specks of pyrites, and also of ferrite. Petrographically they may be referred to the augite-andesites, and occur of irregular shape and size, occasionally appearing upon the surface, but often hidden from view. They never present a *wall-like* mass of mineral matter filling up rents or fissures in the original strata.

A sample taken of the rock about 400 feet below the surface, and near the point of contact with the country rock, shows slickenslides in a very marked manner.

No change of geological interest is observed until the river called Rio Grande is reached. In several ravines near the river deposits

Fig. 4.—*Sketch of Augite-Andesite with Country Rock adhering to it, from the surface near the San Rafael tunnel in the Aguacate Mountains.*



of coal have been discovered. The coal is in three conditions :—one, in which the coal is compact, and in which there is little trace of vegetable structure ; another, in which the plants are partially carbonized ; and a third, which shows the structure of plants (probably dicotyledonous). The coals may be called lignites ; they are highly pyritized, and contain in many places beautiful white crystals of melanterite, also pieces of jet.

Near the coal, and often adhering to it, are found bands of hornstone or chert, of a yellowish-brown colour.

The coal-deposits have not been explored thoroughly, and but little is known at the present time about their extent. From a knowledge of the contour of the country and of the surrounding rocks, I consider it probable that the coal-deposits extend over a limited area only.

We now come to a series of ancient lakes, now valleys, whose waters have been tapped by the Rio Grande, on the Pacific slope, and by the Rio Reventazon on the Atlantic slope (fig. 5). The old water-lines on the mountain-sides, and on the hills, once small islands, in the valleys of Alajuela, San José, and Cartago, are very marked and distinct.

The country rock is the same as above, and continues to within a few miles of Cartago. Augite-andesite boulders are found on both sides of the dividing ridge; and in the valleys of San José and Cartago boulders of trachytic rocks are met with.

Large deposits of a fine-grained soft stone are found collected in some of the ravines near San José and Cartago, having a general white ground, but tinged with yellow, red, and magenta, in fantastic forms. This was found to be a silicate of alumina highly impregnated with iron oxides; in places the stones are kaolinized, and resemble lithomarge.

Near this latter rock are found, more or less connected with it, masses of hard white porcelain-clay, resembling kaolin, or even lithomarge.

A few miles to the west of Cartago, and near the base of the volcano Irazu, the usual country rock is hidden from view, and replaced by a greyish-looking rock, which is coarsely crystalline and rough, and unpleasant to handle, and in which the felspathic crystals predominate (No. 5 in the Appendix, p. 338, is a variety of this rock).

The felspars are chiefly oligoclase; and both grains and crystals of quartz were observed, also a little sanidine, augite, magnetite, and some iron oxides. The rock is a trachyte, and most probably a quartz-trachyte. It is known in the country as the "Cartago Stone," owing to many of the churches and public buildings being constructed of it.

In the several ravines to the south-east of the volcanoes Irazu and Turrialba, deposits of sandstone are found, containing slight traces of decomposed felspar.

In ravines and on the mountain-slopes of the volcanoes Irazu and Turrialba a trachytic rock is frequently found much finer-grained than the "Cartago" rock, but containing less quartz than the coarser crystalline variety. It is probably a quartz-trachyte.

Amongst the large boulders of trachytic rock which lie scattered on the hill and slopes above the town of Cartago numerous volcanic nodules were observed, very close-grained, and of greyish colour, with specks of visible augite. Mr. Hudleston describes it as a felspathic tuff, largely made up of soda felspars (Appendix, No. 7, p. 339). Several nodules were observed about $4\frac{1}{2}$ feet in diameter. They are evidently ejectamenta from either Irazu or Turrialba.

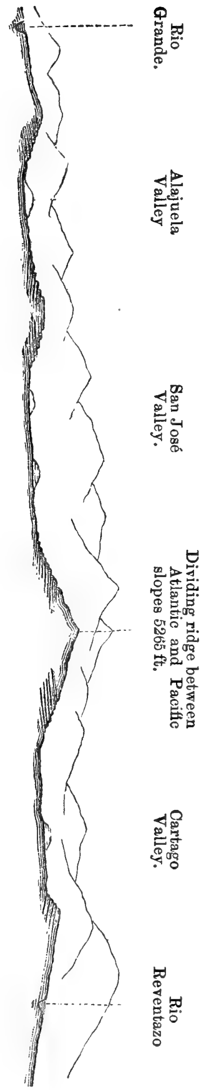


Fig. 5.—*Section showing the ancient lakes, now valleys, of Alajuela, San José, and Cartago.*

Near Paradise Valley and close to Orosi the country rock is a consolidated ash, in which augite-andesite rocks make their appearance through the crust. Dark-coloured boulders are also found in the river-beds and in the valleys. The augite-andesite rock (Appendix, No. 1, p. 336) presents the same characteristics as those found near San Mateo and on the Aguacate Mountains.

In the Valley of Orosi and close to the village there is a small stream called Rio Agua Caliente (hot-water river); and in many places small natural springs were seen, out of which flowed a steady stream of hot water. The temperature of the water was taken, and found to be between 124 and 125 degrees Fahr. The waters are sulphurous, and contain a considerable amount of chloride of sodium, with soda and magnesia carbonates, iron oxides, &c.; they emitted sulphuretted hydrogen and carbonic acid gases, but not to a great extent. The springs have a great resemblance to the hot springs found to the north-west of the city of Salt Lake, Utah, situated near the base of the Wahsatch range of mountains, as well as to several other springs in the neighbourhood.

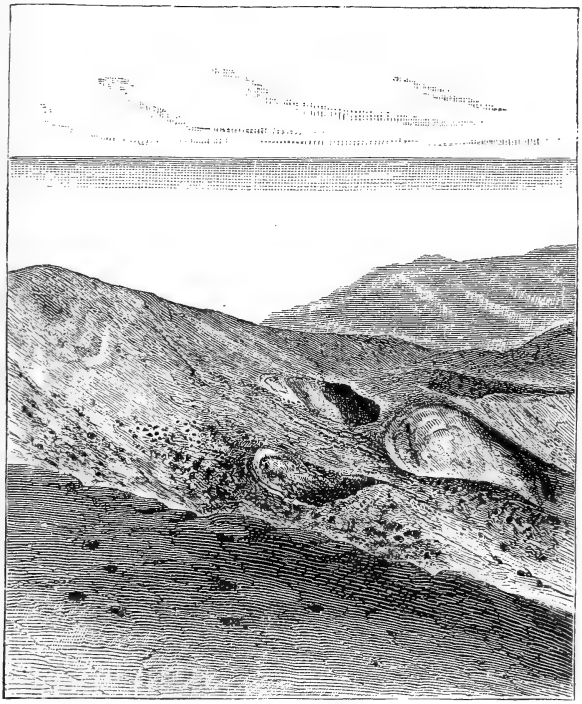
About 12 miles to the north-west of the volcanoes Irazu and Turrialba, at a place called La Palma, some rocks were collected. Mr. Hudleston's description of them (Appendix, No. 2, p. 337) agrees with my examination; and I have called them augite-andesites.

The volcanoes of Irazu and Turrialba present many features of great interest. Irazu is passive, although sulphur vapours are now and then noticeable. It has been quiet since 1841; and immediately after its becoming so a fearful earthquake was experienced, which nearly destroyed the (then) capital of the Republic, Cartago. I append to this a copy of a photograph (fig. 6), showing a portion of the crater, and giving at the same time a general idea of the gas-vents (blow-holes) and of the volcanic ash and scoriæ found. The height of Irazu has been variously estimated. Prof. W. M. Gabb places it at 11,356 feet above sea-level, while Prof. von Seebach, Dr. Don Alejandro von Frantzius, and others make it 11,500 feet above sea-level*.

The volcano Turrialba is still active; but its activity consists chiefly in sending out clouds of vapour with a little ash. During my visit it appeared to me that the volcano was gradually becoming passive and was following the example of Irazu. I experienced numerous but at the same time slight earthquake-shocks at San José and some other places; and since my departure from the country very heavy shocks have taken place. From what observations I was able to make, it appeared most likely that the vents of the crater of Turrialba were becoming choked up, and that the consequences would probably be either a fresh and violent eruption of lava or severe and heavy earthquakes.

* See W. M. Gabb, "Notes on Costa Rica Geology," Amer. Journ. ser. 3, vol. ix. p. 198, &c.; also Lang, "Vulcanische Asche vom Turrialba (Costa Rica)," Nachrichten k. Gesell. Wissen. und Universität zu Göttingen, 1875, pp. 397–411; also Seebach, a paper in Petermann's Mittheilungen, 1865, p. 321.

Fig. 6.—*View of a Part of the Crater of the Volcano Irazu, showing Volcanic ash, Scoriæ, &c., and Gas-vents.* From a photograph taken in the direction of the Atlantic.



Turrialba is about 11,500 feet above sea-level. Many differences of opinion have existed in regard to its height; but the maximum difference is only 150 feet. From my observations Turrialba is about from 60 to 100 feet higher than Irazu.

Conclusions.

The conclusions at which I have arrived from a personal survey and examination of the country which I have just described, and also from the analyses and microscopical examinations made by Mr. W. H. Hudleston and myself are as follows:—

1st. The country rock, or the general representative rock of the country, is a consolidated volcanic ash associated with augite-andesite.

2nd. The filling of the fissures, now mineral lodes, in the Aguacate Mountains took place in the Tertiary age, and most probably in the Pliocene.

3rd. The augite-andesites of the Aguacate Mountains are probably contemporaneous with, and have thus contributed largely to the mineral deposition and formation of the metalliferous lodes.

The veinstone being found more or less mixed up with the decomposed rock, appears to indicate that their ages may be identical.

4th. The quartz-trachytes and sandstone are recent, and most certainly Post-tertiary.

APPENDIX.

REPORT *on some* ROCK SPECIMENS *collected by* MR. GEORGE ATTWOOD. By W. H. HUDLESTON, Esq., F.G.S., F.C.S., &c.

SIX specimens were carefully examined. Five of these are igneous rocks, having all the appearance of lavas; and although considerable differences exist between some of them, yet four out of the five, and perhaps all five, must come within the category of augite-andesites. The hand-specimens show a dark compact base with numerous crystals of felspars, *usually small.* Thus the general structure, viewed macroscopically, is micro-porphyritic. In most cases the felspars are inclined to be vitreous; but in one instance, where the crystals are rather larger, they are of a dull white.

The character of the ground-mass in thin section is seen to range from a trachydolerite, where there is a considerable development of microcrystalline matter, consisting for the most part of acicular prisms of triclinic felspar, to a rock in which the felsitic texture is in the ascendant and the tendency to doleritic texture is reduced to a minimum.

Generally speaking, the felspars are fresh, and polarize with considerable brilliancy. They are mostly triclinic, though not without orthoclase (sanidine) in some cases. Without analysis it is impossible to state positively what the triclinic felspars may be, though probably oligoclase is the most abundant. Judging from the analogy of similar rocks, andesine is also present; but the more basic varieties of felspar are probably rare or absent.

There is a fair amount of very fresh augite, in crystals which are smaller than those of the felspars and less numerous. Associated with these augite crystals, and sometimes independant of them, occurs a fair amount of magnetite or pyrite, which in some cases has undergone partial oxidation. The accessory minerals are by no means plentiful, though one may note a stray needle of apatite here and there. If any olivine exists, it must be in very small quantity; but some of the augite crystals are so rounded at the edges that they might perhaps be taken for grains of olivine.

The specific gravity ranges from about 2·55 to 2·80, being on the whole rather low for rocks with some augite and so much triclinic felspar in addition to a fair proportion of iron minerals. This circumstance is an additional point in favour of the notion that in most cases the bulk of the felspar is oligoclase. Furthermore the microscopic examination would lead one to believe that the specimens for the most part belong to a class of rocks intermediate between the dolerites and the acidic trachytes.

No. 1. "*In situ,* Paradise Valley." Specific gravity 2·76. Black

compact matrix, full of small crystals of glittering felspars porphyritically distributed. This rock has undergone but little alteration.

In thin section the ground-mass appears black with a greenish grey tinge. It is opaque and granular, but relieved by a moderate display of small triclinic felspars. On the whole, however, the felsitic texture prevails over the doleritic or microcrystalline.

The large felspar crystals are numerous and clean at the edges, contrasting well with the ground-mass. They are probably all triclinic, and polarize with great brilliancy. Some are tolerably free from inclusions; others contain quantities of the base, which frequently occur in fantastic arrangements.

The augite crystals are not numerous, or large, but are well defined, and, like the felspars, polarize very effectively. There are several specks and triangular pieces, which present the same optical properties and probably belong to the same species. The iron mineral is mostly magnetite, but is far from being plentiful.

No. 2. "*In situ*, La Palma, N.W. of Turrialba." Specific gravity 2·82. A somewhat scanty grey matrix full of crystals of a white felspar larger than in the last specimen, less vitreous, and rather prone to kaolinize. The augite crystals, associated with some iron mineral, are quite obvious in the hand-specimen, which is less compact and more porphyritic than No. 1.

In thin sections the ground-mass is seen to be grey, opaque and woolly; so that in this case the felsitic texture predominates, to the almost entire exclusion of the doleritic or microcrystalline, notwithstanding the fact that this is the most dense of all the specimens.

The large felspars are not so clean-cut as in No. 1, and are more contaminated with included portions of the ground-mass, which, in one or two cases, are yet in the condition of glass towards the centre of the inclusions. Still the felspars polarize with much brilliancy and, with one exception, are all markedly triclinic. Andesine may constitute a considerable portion of them. With great care it might be possible to obtain a sufficiency for an analysis.

The crystals of augite are fairly numerous, smaller as a rule than the felspars, with a tendency to be grouped in bunches, in which case they are much intermingled with an iron mineral. Some very characteristic forms occur, such as it is impossible to mistake. Pale yellow to greenish yellow in ordinary light, all these augites polarize very effectively, in which case the numerous inclusions of the same mineral are very conspicuous. When the angles are rounded, such crystals become oval or almost circular in section. The iron mineral, presumably magnetite, in some cases evinces a tendency towards the formation of limonite at the edges; and this rust-coloured stain is communicated to some of the crystals of felspar and augite. There are appearances also of pyrites in a limited portion of the polished surface from which the slice has been cut.

No. 3. "San Mateo Boulders." Not examined closely. Near to No. 1, but with a more felsitic ground-mass.

No. 4. "Black Rock, Lower San Rafael Level." Specific gravity 2·72. A very compact rock, brownish-black, lustreless, and but

slightly conchoidal in fracture. Largely charged with small crystals of pyrite, chiefly in cakes. Contains crystals of a somewhat vitreous felspar in moderate amount, together with some augite. Structure microporphyritic.

In thin sections the general mass appears of a brownish black colour, very opaque and granular, but relieved by numerous small prisms of triclinic felspars, more than in any of the other specimens. In this case the granular or felsitic texture and the microcrystalline or doleritic texture occur in almost equal amount. It would seem therefore to be a well-balanced trachydolerite.

This being less porphyritic than the two previous specimens, the large felspars are not so numerous, and are, on the whole, in worse condition. The inclusions of ground-mass in the crystalline matter are less well contrasted; and in some cases a certain amount of granulation has supervened. Still the crystals polarize fairly well, though the triclinic character is not so strongly marked, and there are appearances which would lead one to suspect interlamination or mixing of orthoclase. A crystal or two of sanidine may be noted.

The augites are mostly small, and not very numerous. Besides one or two characteristic forms, frequently much rounded at the angles, there is one large triangular piece with well-defined edges which evidently belongs to this variety of pyroxene. Pyrite and, perhaps, magnetite occur sporadically in small crystalline forms; and, besides this, the opacity of the base is much increased by numerous small dots of ferrite, which may include both the previously mentioned species.

No. 5. "Cartago Rock." Specific gravity 2·54? A trachytic rock; matrix close, and of a grey colour, rather prone to fracture, and studded with felspars, mostly glassy and brittle. The specimen examined was very full of air, owing to cracks and to the cavities resulting from the fractured crystals of felspar.

In thin section the ground-mass appears greyish; it is highly felsitic in texture, there being but little trace of microcrystalline matter. Hence this specimen scarcely comes within the group of trachydolerites, but approaches the acidic trachytes more than any of these lavas. The ground-mass occupies a large proportion of the slice.

Most of the felspars, even in this specimen, are triclinic, and are probably mainly oligoclase, but with some which I take to be sanidine. The inclusions are small and mostly granulated, like the base, but occasionally in a state of glass. As a whole they are in good condition, and polarize with great brilliancy. Many of the felspars break out on grinding, so that it has not been easy to select a slice sufficiently free from flaws.

The augites are fairly numerous; one long greenish crystal is more dichroic than the rest, and may be slightly altered. Several of the crystals, as usual, have their angles much rounded, presenting in one or two instances a pyriform shape. The majority are fresh, and polarize well. The iron mineral is mostly magnetite, often in well-defined octahedra, but in some cases having a tendency

to further oxidation at the edges. The smaller ferrites are not numerous.

There is an anomaly in connexion with this specimen which, unless due to faulty observation, one cannot well explain. A rock with a fair amount of triclinic felspar, presumably oligoclase, and some augite might be expected to have a higher specific gravity than 2·54. Even the lightest sanidine-oligoclase-trachytes are stated by Von Cotta to have a specific gravity of 2·6. It is just possible that the specimen contains cavities not accessible to water under ordinary pressure.

No. 6. "Los Castros rock, Aguacate Mountains." Specific gravity 2·78. An extremely close-grained rock of a dark-green colour and subconchoidal fracture, with only a moderate quantity of felspar crystals porphyritically distributed. Pyrites in small crystals, not scarce.

In thin sections the ground-mass appears of a greenish-grey colour, and is woolly and thoroughly dusted with small round ferrites, opaque, and little relieved by microcrystalline matter. Hence the texture is felsitic rather than doleritic.

The felspars are probably all triclinic. Though perfect in outline, they are so much suffused and granulated as to suggest the idea of partial decomposition; consequently their optical properties are feeble, and they stand out less distinctly from the base.

The augites polarize with great brilliancy, and are very characteristic. The iron minerals, probably both magnetite and pyrite, seem much mixed up with the augite crystals.

The augites constitute the principal feature in this rock, whose ground-mass is obviously more tinged with green in the vicinity of these groups of crystals than elsewhere. If the idea of greenstone were not so much associated with hornblende, of which I cannot in this specimen find a trace, one might almost call such a rock a "greenstone-andesite." In some respects it reminds me forcibly of certain "felsi-dolerites" occurring in the English lake-district.

No. 7. "Volcanic nodule, Turrialba." The specific gravity of this specimen is low. It is a light-grey fragmental rock, tolerably close in texture, and in the hand-specimen shows a somewhat gritty matrix with black specks. Tolerably opaque in thin sections, but slightly seamed with translucent cracks. The few crystalline fragments are much decomposed, and muddled with a brownish ferrite; specks of augite may be noticed.

The rock is doubtless pyroclastic; and if we may judge from the lavas previously described, it is a felspathic tuff largely made up of soda felspars.

No. 8. "Near Rio Barranca." Not examined closely. More coarsely fragmental than the last. Largely made up of soda felspars much kaolinized.

EXPLANATION OF PLATE XII.

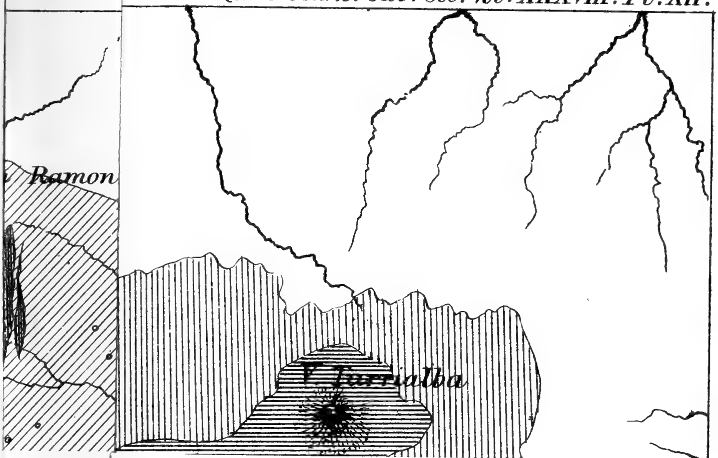
Geological Map and Section from Punta Arenas, on the Bay of Nicoya, to the Volcanoes Irazu and Turrialba, Costa Rica.

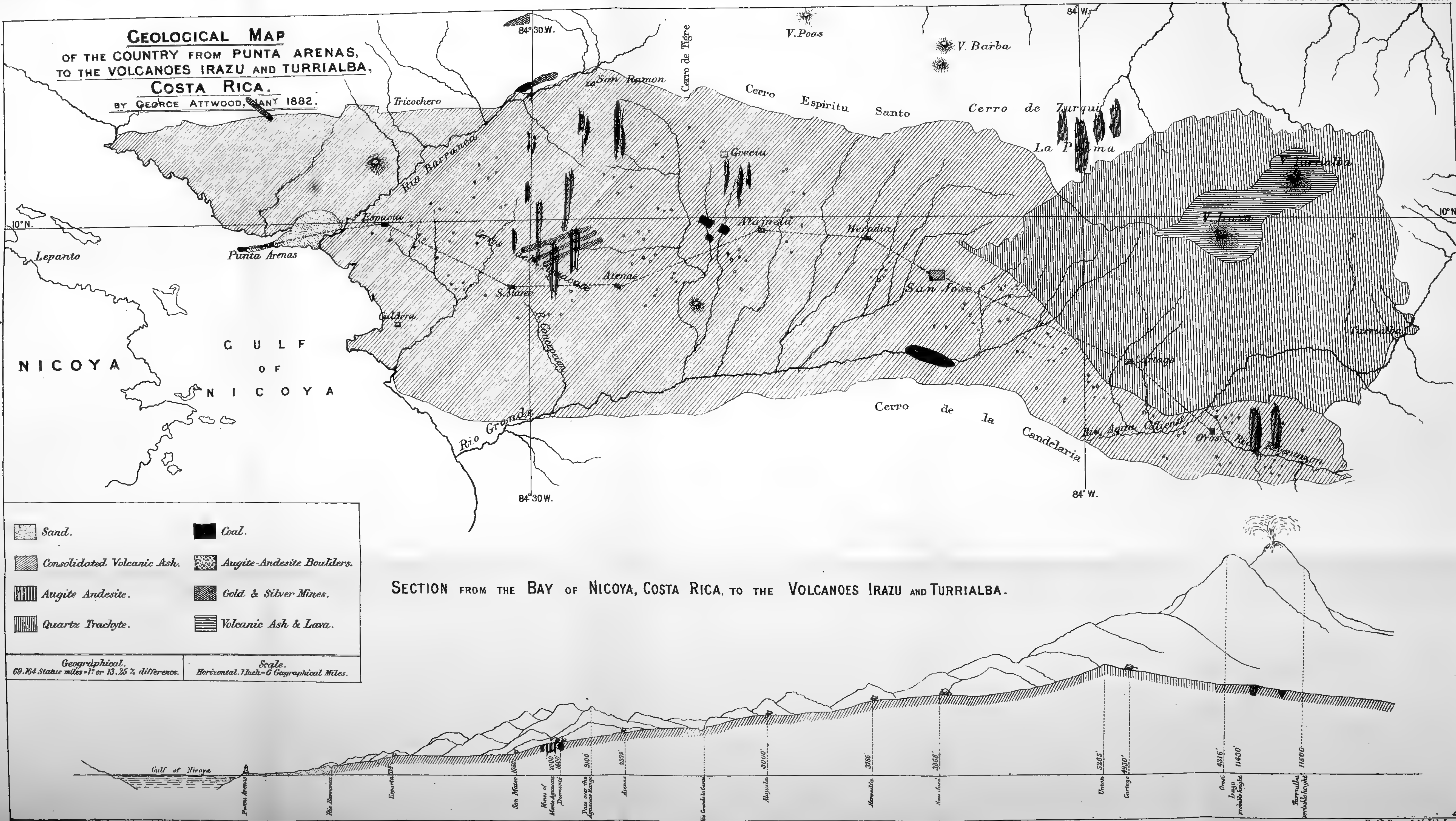
Discussion.

Mr. Bauerman expressed his sense of the value of a section made in a little-known country. It was an interesting question, looking at the comparatively modern date of the igneous rock described and the absence of schistose rock, whether the seas had previously communicated. As for the condition of the transformed masses of rock containing minerals, he was glad to find Mr. Attwood had observed it; for he had noticed the same thing in Spain and North America, and thought that it had been too often overlooked in the search for lodes.

Mr. Warington Smyth said he should like to ask Mr. Attwood on what grounds he stated that there were no more ancient rocks than those which he had seen. Had not vegetation possibly masked them, and might not there be granitic rocks to furnish the kaolin? Was the coal merely carbonized stems or a true lignite? Was the entire run of the veins metalliferous?

Mr. Attwood said that he had not himself seen any other case of metalliferous rock like those which he had described. Very likely the oceans had once communicated. He saw no signs of granite in the country. As for the vein-matter in the lodes, he thought that the augite-andesite and the fissures in which these lodes occurred were of about the same age. The coal was only limited in area, but varied from partly carbonized matter to true lignite. The sandstones, like the coal, were only found in the ravines near the volcanoes, and were of small area.


Ramon
V. Turrialba



Fred^k Dangerfield, Lith. London.

34. Thamniscus: *Permian, Carboniferous, and Silurian.* By George W. Shrubsole, Esq., F.G.S. (Read April 26, 1882.)

The genus *Thamniscus* was founded in 1849 by Prof. King for a Polyzoan of large size found in the Permian beds of the north of England. The main interest of the genus consisted in Prof. King claiming for the type species the possession of certain "denticles," "vesicles," and "hemispherical bodies" similar to those observed in "certain Lunulites and *Cellaria salicornia*"*. Prof. King further institutes comparisons between these peculiarities in his genus and some of the recent forms of Polyzoa formerly included among *Elasmopora*, *Escharina*, and *Cellepora*†. It is needless to say that these features at once assign the genus to the order of Chilostomatous Polyzoa; and as such it is entitled to rank as the most pronounced type of its class found among the Palæozoic Polyzoa. How far these characters can be sustained will be the subject of after inquiry. The next reference to the genus that I find is in 1874, when Mr. R. Etheridge, Jun., described, as found in some Scottish Carboniferous Limestone shale, a fragment of a Polyzoan which he thought might be a new species of *Polypora*, at the same time remarking that the disposition of the cells and the mode of branching were exceedingly like those seen in the type species of *Thamniscus* (*T. dubius*, King), and suggesting that it might be a species of that genus‡.

In 1875 the Messrs. Young, of Glasgow, described (under the name of *Thamniscus Rankini*) a free, robust, branching Polyzoan which they had received from Dr. Rankin of Carluke, and which is probably identical with the species referred to by Mr. R. Etheridge, Jun. At the same time they remark that the generic position of the fossil is uncertain; and if the "gemmuliferous vesicles" described by Prof. King are essential to *Thamniscus*, this character is wanting in their species, even in the best-preserved specimens§. After further discussing its position they conclude by saying, "we think it safer to leave it in the Palæozoic genus *Thamniscus*." There is very little doubt about the correctness of this reference, since it is an undoubted *Thamniscus*.

As yet I have no record or trace of *Thamniscus* being found in the Devonian rocks, and therefore pass on to the Silurian species.

I have long been familiar with fragments of a Polyzoan in the Dudley Limestone which bear a general resemblance to the Permian *Thamniscus*; but the fragmentary condition of the remains forbade description. Recently I have found in the Woodwardian Museum, labelled by Salter *Ceriopora*, a fine specimen of the same, in which the growth, habit, and cell-pore are sufficiently displayed to

* Perm. Foss. England, p. 45. † Ibid. p. 46.
‡ Mem. Geol. Surv. Scotland, Explan. Sh. 23, p. 102.
§ Ann. & Mag. Nat. Hist. 1875, vol. xv. p. 336.

admit of specific description, and a determination of its affinities, which in outline are clearly with the Thamniscidæ.

This Silurian Polyzoan has had a somewhat chequered palæontological history. It was known to Lonsdale as *Hornera crassa*; in 'Siluria' it is referred to *Polypora*; Salter in his 'Catalogue' refers to it as a doubtful *Ceriopora*; in the Woodwardian Museum it is labelled *Ceriopora*; by other authorities it is regarded as a *Polypora*.

In determining its true affinities it will be sufficient to state that, as only one half of the surface is poriferous, it clearly does not belong to the Cerioporidæ, which are poriferous on all sides. The absence of dissepiments, which are a distinguishing mark of *Polypora*, further excludes it. Its relation to *Hornera* is the more feasible on account of a certain amount of outward resemblance, but equally fallacious, since the cell-arrangements of *Hornera* are widely distinct.

There remains, then, the Permian *Thamniscus* with which to compare it. With this genus, in habit, growth, and cell-arrangement, there is a very close agreement, with the one exception of its wanting the peculiar adjuncts to the cell which relegate the Permian species to the Chilostomata, the Silurian form being clearly Cyclostomatous. In this respect it agrees with the Carboniferous species of *Thamniscus* described by Messrs. Etheridge and Young. At this point an interesting inquiry arises as to the generic identity of these three species; and also does the later, Permian species, to take an extreme view, owe its peculiarities in any way to further development? To set these questions at rest, I decided upon investigating the claim of the Permian species to the possession of these exceptional characters; for it must be confessed that they are so anomalous, and among the Palæozoic Polyzoa so unique, that it is highly important that there should be no doubt upon the point. In elucidating the question as to the existence or otherwise of these cell-adjuncts, the resources of the Newcastle Museum have been placed at my disposal. To Mr. Howse of Newcastle I am especially indebted for much assistance.

The result of a careful microscopic examination of the poriferous face of several specimens of *Thamniscus* is, that I find no confirmation of Prof. King's claim for his species of having affinity with recent forms and possessing appendages homologous with theirs. I refer now more especially to the secondary cell-pore. On the contrary, I find, as to cell-character, a perfect agreement between Permian, Carboniferous, and Silurian species. I do notice, however, on the cell-face of *Thamniscus dubius*, a feature not recorded by King, and one which is very common in the Palæozoic Polyzoa—a strong defensive spine which is hollow at the base; it occurs here and there in an irregular line between the cells; more often than not it is worn down, showing the hollow centre and projecting circular walls. I have little doubt that the "hollow cavities" and the secondary cells of King are nothing else than the hollow centres of these spines. Spines, when worn away, which is more often the case than otherwise, have often been mistaken, in the Palæozoic Polyzoa, for minute

cells and "gemmuliferous vesicles." The supposed occurrence of these secondary cells, as shown by King*, in a single irregular line along, and not extending across, the face of the branch, is in perfect agreement with the mode of occurrence of the spines I have indicated.

Again, as to the "denticle-like process "† said to be possessed by *Thamniscus dubius*; I can only trace this to the unequal wearing-down of the cell-mouth, which may often be seen on the protected side of the branch, prominent and circular; this is seen to weather unequally, and the more prominent portion remaining becomes the denticular process. The perfect cell-aperture is circular and well defined; the denticular process is therefore an accident, and not a natural occurrence.

These details are necessary to justify the course which I intend to take; for with the discovery of Carboniferous and Silurian Thamniscidæ, it is obvious that if King's diagnosis of the genus is correct, then a new genus would be necessary to receive them. Happily it has been shown that this addition is not needful. Take away the supposed cell-adjuncts and the denticulate aperture, for which I find no warrant, from the Permian species, and the whole of the series are in perfect accord.

Thamniscus dubius is very fully described and figured by King. As to the drawings of it, I can only admit fig. 9 as typical of the poriferous branch, the rest are misleading. Fig. 10, intended for *Thamniscus*, really represents the basal branches of *Synocladia virgulacea*; these differ very materially in appearance from the upper and the more characteristic portion of the zoarium. The difference is due to a thickening and solidifying of the branches which is needful to carry the large expansion of *Synocladia*. In the future reading of the genus *Thamniscus* it will be necessary to omit the reference to "gemmuliferous vesicles," retaining as its distinctive character frequent and regular bifurcation of the branches.

As King's generic description is faulty as well, it will be necessary to redefine the genus, and also to give a new description of the Permian species.

Thamniscus, King.

Branches free, round, frequently and regularly bifurcating; more or less on one plane. Zoœcia on one side. Cells immersed, round, arranged in oblique lines.

Thamniscus dubius, King.

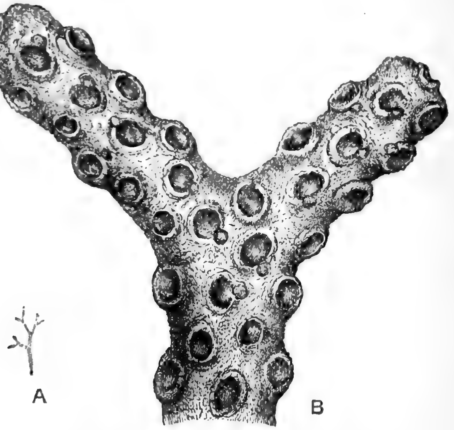
Sp. char. Zoarium a flattened expansion. Branches free, thick, round, somewhat flattened, frequently dividing. Zoœcia on one side of the branch, immersed; apertures circular; peristomes prominent, about their own diameter apart, arranged in regular lines, both longitudinal and oblique, a slight wavy line between the longitudinal rows. Reverse finely striate. Remains of spiniferous processes

* Perm. Foss. England, pl. v. fig. 11 *b*.
† Ibid. pl. v. fig. 12.

here and there. Six cells in one line longitudinally, from three to six cells on the width of a branch.

The habit of growth in *Thamniscus* is characterized by the branches being free and regularly divided. This readily distinguishes it from any associated Polyzoan. It scarcely merits the variable character which Prof. King gives to it when he speaks of "almost every specimen offering a modified aspect"*. Much of this confusion may be due to the obscurity invariably present in the Permian Polyzoa, owing to the incrustation of calcic carbonate which often hides their true features. Owing partly to this cause, I notice that a fragment showing irregular branching and anastomosis of the branch is indicated as an instance of *Thamniscus* simulating the character of *Synocladia*†. The drawing in question is clearly that of *Synocladia* and not *Thamniscus*‡. This dichotomization of *Thamniscus* is a well-marked and distinguishing feature, and forms a good generic distinction; and hence, in redescribing the genus, I have characterized the branches as regularly instead of "irregularly bifurcating."

Thamniscus crassus, *from the Wenlock Limestone near Dudley.* (From drawings by Rochfort Connor, Esq., from a specimen in my cabinet.)



A. Natural size. B. A portion of the same, showing the cells and position of the spiny processes, enlarged 25 diameters.

The Upper Silurian species from the Dudley Limestone I propose to describe as

THAMNISCUS CRASSUS.

? *Hornera crassa*, Lonsd. Sil. Syst. p. 677, pl. 15. figs. 13, 13 *a*.
? *Polypora crassa*, Siluria, p. 215, Foss. 35 (i.).
Ceriopora, Salter, Cat. Cambr. Foss. p. 100.
Hornera crassa, Vine, Quart. Journ. Geol. Soc. vol. xxxviii. p. 60.

* Perm. Foss. England, p. 45. † Ibid.
‡ Ibid. pl. 5, fig. 10.

Sp. char. Zoarium a flattened expansion. Branches round, somewhat flattened, regularly dichotomizing at intervals of two or three lines. Diameter of branch $\frac{1}{20}$ to $\frac{1}{30}$ of an inch. Reverse striated longitudinally. Zoœcia long and cylindrical, tapering towards the mouth, raised margins more than their own diameter apart when not eroded; spirally arranged one side of the branch, three or four cells across, and five or six in oblique lines. Spines on the interspaces between the cells.

Locality. Wenlock Limestone, near Dudley.

Large specimens somewhat rare, small fragments more common.

Obs. The specimen of *Thamniscus* in the Woodwardian Museum, while it is the largest and best-preserved fragment that I have seen, bears evidence of having suffered from lateral crushing and breakage, which interferes somewhat with the characteristic display of its growth. The seeming coalescence of the branches is the result of this lateral pressure.

It is often seen in this class of organisms that the best-preserved portion of the structure is near the base. This is the case here. On the basal branches will be seen the remains of large spines half the diameter of the cells in size. The cell-openings, it will be observed, are circular, with considerable interspaces between them; comparing these with other and more eroded parts of the branch, it will be seen that in the latter the interspaces have decreased, and will, with further erosion, altogether disappear, leaving the cells with only the division-walls between them. The explanation is that while the cells of *Thamniscus* are cylindrical, they are also tapering, the base of the cell being the wider part, and twice the diameter of the aperture. The cell-aperture was an important as well as a peculiar feature. All that is now to be seen of it are the remains of the cell-walls, which appear springing from the body of the cell. It might be compared, as far as the outline of the aperture is concerned, with a somewhat eroded cell of *Glauconome stellipora*, Young. As to the existence of denticles there is no evidence forthcoming.

I may here notice, as showing the agreement between the Carboniferous and Silurian *Thamnisci*, that the Messrs. Young, when describing the former, speak of the cell-aperture as tuberculate; this quite describes the appearance of the Silurian species in parts where not eroded. Indeed the cell-neck might be said to be built up of a series of pillars, arranged in a circle, judging from their present tuberculate appearance.

Fragments of this Polyzoan are not uncommon in exposures of Dudley Limestone; and Mr. Vine informs me that he has found it in the Wenlock shale, with characters identical with those above described. From the robust character of the fragments it may be inferred that it attained considerable size; its expansion was probably fan-shaped, although the fragments I have seen would not be inconsistent with an open cup-shaped zoarium. It may readily be distinguished by its branches of equal width, regularly dichotomizing and not anastomosing. It closely resembles a *Polypora* without the connecting bars; indeed it might be so described. Most of the

Palæozoic Polyzoa, when seen under favourable circumstances, are found to have been protected by spines either long or short. In this respect *Thamniscus crassus* is no exception; for notwithstanding the natural and often artificial weathering to which the Dudley fossils are subject, there are still to be seen little irregularities on the surface, which when seen in profile leave no doubt as to their being the remains of spines; this is confirmed by the observations of Mr. Vine, who has noticed the base of spiniferous processes in fragments from the Wenlock shale*.

As yet we know of only the three species of *Thamniscus* which I have referred to as occurring severally in the Silurian, Carboniferous, and Permian periods. We have least knowledge of the Carboniferous species, for the reason that as yet it has only been found in fragments. The Silurian species is probably the more compact in growth, and the Carboniferous and Permian the more vigorous; the last is more outspread in its bifurcation. As yet I know of no older form than the Dudley species.

I have to acknowledge my indebtedness to Prof. T. M'Kenny Hughes, for giving me facilities for studying the Polyzoa of the Woodwardian Museum.

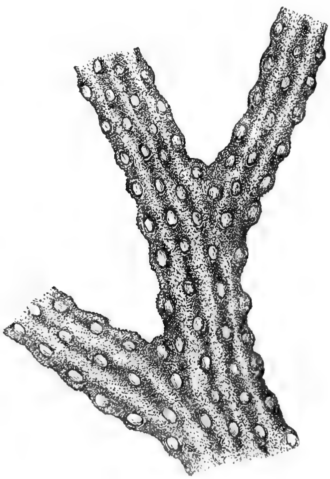
* Quart. Journ. Geol. Soc. vol. xxxviii. p. 60.

35. *On the* Occurrence *of a* new Species *of* Phyllopora *in the* Permian Limestone. By George W. Shrubsole, Esq., F.G.S. (Read April 26, 1882.)

Among some Permian Polyzoa which Mr. Howse, of Newcastle, entrusted to me for examination was one labelled "*Fenestella ramosa.*" This I at once saw was not a *Fenestella*, but a *Phyllopora*, King, a new and, as yet, undescribed species.

The genus *Phyllopora* was rightly founded by King * to receive the Permian and Silurian species of Polyzoa which, prior to that time, had been referred to *Retepora*. In accordance with this view Mr. Vine has recently shown that among the ancient Polyzoa, so far as at present ascertained, we have none of the peculiarities of cell-growth which are characteristic of the recent *Reteporæ* †; in short, that we have no Retepores among the Palæozoic Polyzoa. All such so-called Retepores should be now assigned to *Phyllopora*, King. The genus *Phyllopora* has as yet been but imperfectly worked; its rarity in the more recent and its imperfect preservation in the older rocks go far to account for this. It is of interest as one of the earliest of our Palæozoic Polyzoa.

Phyllopora multipora, *from the Permian Limestone near Sunderland.* (From a drawing by Rochfort Connor, Esq., from a specimen in the Newcastle Museum of Natural History.)



A portion of the zoarium, showing the arrangement of the cells, enlarged 25 diameters.

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* Permian Foss. England, p. 40.

† Brit. Assoc. Rep. on Fossil Polyzoa, p. 3.

PHYLLOPORA MULTIPORA, sp. nov.

Spec. char. Zoarium an open network of anastomosing branches; base solid, forming an infundibuliform or folded expansion; branches regular, flattened, dichotomous, anastomosing; on poriferous face a wavy ridge between the longitudinal lines of cells; reverse face smooth; fenestræ ovate, with pointed ends, $1\frac{1}{2}$ line in length; zoœcia immersed, small, prominent, and projected when not worn down, twice their diameter apart, arranged in longitudinal lines having an oblique direction. Six or seven cells in one line longitudinally, and four or five in one line transversely.

Loc. In a Permian Limestone quarry, Hylton Castle, near Sunderland.

Obs. The present species may be readily distinguished from the other Permian Polyzoa by the minuteness of its cells. Hence, in a given space, *Phyllopora multipora* will be found by comparison with all other species to have double the number of cells. From allied forms it may be known by the ovate fenestræ.

There are probably two distinct species, or types of species, of *Phyllopora*, ranging from the Lower Silurian to the Permian era. The type of each species is most distinct and persistent. The zoarium of the one may best be described as solid and massive, having circular apertures or fenestræ, in which the branch is lost in the solidity of the zoarium. In the other type the zoarium is a network in which the branch is seen to interlace and coalesce, giving rise to fenestræ either square, ovate, or lozenge-shaped, more frequently the latter. In both types there is an absence of dissepiments, and the whole of the poriferous face is crowded with the characteristic small cell-apertures.

Notwithstanding the little work that has been done in connexion with *Phyllopora*, there is yet evidence forthcoming of the existence of the types I have mentioned. In the Lower Silurian rocks *Phyllopora* is most abundant. There are at least two distinct species, if not more. The preservation of the remains in these beds is most unfavourable for exact work, occurring, as they often do, in coarse ash or shale and distorted by cleavage.

From the Devonian rocks Phillips figures the *Phyllopora* with circular fenestræ as *Retepora prisca**, that with lozenge-shaped fenestræ as *Fenestella arthritica* †, and that with square fenestræ as *Gorgonia ripisteria* ‡. As might be expected, there is considerable confusion of species in Phillips's delineation of the Devonian Polyzoa. Two or more varieties are included under one head. A revision of the Devonian Polyzoa from a palæontological point of view is very desirable, for since Phillips's work, forty years ago, they have remained untouched. The difficulty is to procure the material necessary for the purpose.

In the Carboniferous rocks *Phyllopora* is comparatively rare in

* Phillips, Pal. Foss. pl. xiii. fig. *c*.
† Ibid. pl. xii. fig. *e*.
‡ Ibid. pl. xi. fig. *b*.

the British area. It has been seldom found in England. I have one example from Derbyshire. Mr. John Young informs me that it has not been found in Scotland. Prof. M'Coy, however, figures it among the Irish Carboniferous fossils.

Good examples of the several types of *Phyllopora* will be found figured in the works of Prof. de Koninck, Dr. Toula, and Mr. Prout. Coming to Permian times, we have in *P. Ehrenbergii* * the form with circular meshes. The new species which I have described supplies the other type.

* King's Perm. Foss. p. 43.

36. *On* Neusticosaurus pusillus (*Fraas*), *an* Amphibious Reptile *having* Affinities *with the* Terrestrial Nothosauria *and with the* Marine Plesiosauria. By H. G. Seeley, Esq., F.R.S., F.G.S., &c., Professor of Geography in King's College. (Read March 22, 1882.)

[Plate XIII.]

Mr. Julius Hoser, of Stuttgart, submitted to me in June 1881 two of the most interesting Saurians ever discovered in the Trias. They were found in the Lettenkohle, which lies between the Upper Muschelkalk and the Keuper, in a quarry at Hoheneck, near Ludwigsburg, about nine miles north of Stuttgart. These fossils are the materials briefly noticed by Dr. Oscar Fraas in the 'Württembergische Jahreshefte,' 1881, and figured as *Simosaurus pusillus*. This animal is probably the smallest representative of the Plesiosauria yet exhumed; but it has a greater interest in exhibiting in the hind limbs all the characteristics of a land animal, while the fore limbs have become paddles, in which a more striking approximation is made to *Plesiosaurus* than was previously known in any Triassic representative of this order. Yet, in form of vertebræ and proportions of the vertebral column, in structure of the pectoral and pelvic girdles and conformation of their component bones, the Plesiosaurian common plan is so closely adhered to that no doubt can attach to the animal's systematic position. A photograph showing the condition of the principal slab when first discovered, which was taken as a record, in case of accident during its development from the matrix, satisfactorily attests that the bones are in their natural positions, and thus enables us to recognize in this animal a terrestrial Plesiosaurian in process of undergoing those structural modifications which would adapt it for aquatic life.

This is the first occurrence of a fairly complete Plesiosaurian skeleton in the Trias. None of the remains so admirably illustrated by von Meyer, and referred to *Nothosaurus*, *Pistosaurus*, *Conchiosaurus*, and *Simosaurus*, exhibit the skull in association with the vertebral column, or either with the limb-bones. The latter, indeed, have only been recovered in isolation from each other; and though the association of bones in certain quarries fully justified von Meyer in his cautious reference to *Nothosaurus* of the various elements of the skeleton, no restoration has been attempted. Even in the admirable analysis of the characters of this genus given by Prof. Owen in his 'Palæontology' (2nd edit.), the diagram (fig. 90, p. 230) of principal characters represents the fore limb as unknown*. In studying this new fossil we need to remember that the genus *Simosaurus* is founded upon the skull, of which both superior and inferior aspects are well known†.

* Von Meyer would have regarded the limb represented as a fore limb.

† Fauna der Vorwelt, Saurier des Muschelkalkes, pls. 16–20.

The superior aspect of the skull is remarkable for the large size of the temporal fossæ, orbits, and nostrils, the latter having a very forward position. The palate, on the other hand, is remarkable for its extensive ossification (pl. 17); and, as Professor Owen has observed, the pterygoids form a broad, expanded, unbroken, flat, imperforate expanse of bone, united by a median suture, and underlapping the sphenoid. The only large perforations on the palate are those beneath the anterior nares and those external to the pterygoids. If we now turn to the skull of the little animal figured by Dr. Fraas, the exposed surface, which he identifies as the palate, shows exactly that arrangement of vacuities which von Meyer figures (pl. 18) as distinctive of the superior surface of the head. There is, however, no reason to question the accuracy of Dr. Fraas's topographical identification, since the exposed surface is concave, as only the palate could be, shows alveoli, and has no trace of a parietal foramen, though the bones are too perfectly ossified and blended to permit of their individual definition in detail. But such a palate as the specimen exhibits makes reference of the species to *Simosaurus* impossible. Equally impossible is it to refer the type to any other genus hitherto instituted. The difference, indeed, is of a subordinal rather than a generic quality; for since all the allied Triassic genera hitherto known have the palate closed, in harmony with the Plesiosaurian plan (and it may be in relation to aquatic conditions of life), here we may have an indication of the kind of skull from which the Plesiosaurian type was originally derived. It has therefore appeared desirable to offer to the Society some further details of the anatomical structure of this animal, which I was enabled to study by the courtesy of Mr. Hoser, before the skeletons became finally deposited in the national collection at South Kensington.

The larger specimen (Pl. XIII. fig. 1) lies on the back in a slight sigmoid curve, and exposes the abdominal aspect of the skeleton, all the bones of which are *in situ* except some elements of the pectoral girdle, the abdominal ribs, and parts of the limbs, which are lost. The extreme length of this skeleton as it lies hardly exceeds 270 mm., though Mr. Hoser measuring the separate regions makes it 285 mm.

The second and somewhat smaller individual (Pl. XIII. fig. 3) exposes the dorsal aspect of the bones, but has lost the head and anterior part of the neck, the extremity of the tail, some of the smaller limb-bones, and the right hind limb. But though the conformation of the bones is slightly different in this animal, the differences are no more than may perhaps be attributed to sex or age.

The Head.

The head (Pl. XIII. fig. 2) is nearly 3 cm. long, and is 14 mm. wide in the posterior or quadrate region, where it is widest: the sides are at first nearly parallel, and then taper forward in a lanceolate shape. It lies flat, and has been carefully excavated so as to display the several regions of the palate. In front, resting close upon the maxillary bones, there appears to be a small fragment of the lower

jaw, still containing three teeth, two in one ramus and one in the other. These teeth are directed outward and upward; they are white, with a cylindrical fang, and a slightly expanded crown; but the fragment of lower jaw is very small and slender; it obscures the anterior termination of the snout so that the premaxillary bones are not seen. The maxillary bones extend backward to the region of the orbits, and appear to have been about 18 mm. long. The sockets for the teeth are circular, and about half a dozen can be counted on the left side of the specimen. The alveolar border is elevated on the inner margin of the sockets. The palatal plates of the maxillary bones are moderately developed in front of the palatal nares; they do not meet in the median line, but rest upon a vomer, which is either double or grooved in the middle. The palatal nares appear to have been ovate, but the posterior border is not clear; they approach to within 6 mm. of the anterior extremity of the head as preserved with the lower jaw. Posterior to the nares, the palate is deeply concave from side to side. This concavity is due, in part, to the mode of development of the palatine bones, though their limits are not clearly defined. They appear to be narrow in front, and to widen in a V-shape behind, and to have the posterior border concave. I am unable to recognize with certainty any suture between them. The posterior processes diverge towards the thickened part of the maxillary bone, where the teeth appear to terminate. There is a median ridge on the palatine, which dies away posteriorly; thus the palatines appear to form the posterior roof of the nares. They terminate backward in a sharp ridge. Posterior to this ridge, which is 13 mm. from the snout, the palate becomes concave from front to back, and appears to include two pairs of vacuities. The smaller pair is in about the middle of the skull, and probably just below the orbits, which are not seen. The two pairs of vacuities appear to be separated from each other by the transverse bone, which is only preserved on the left side, and unites with the hinder margin of the maxillary and with the pterygoid bones. The pterygoids divide the anterior pair of these vacuities from each other; they appear to show a median suture, are much constricted from side to side, but diverge posteriorly; they are short, and it is not possible to speak with certainty of their posterior limit, since no sutures can be accurately defined, and the large mass of bone between the hindermost pair of palatal vacuities has all the characters of the basisphenoid. This region is broadly channelled in length, its lateral margins are concave; and posterior to it is the basioccipital. It gives attachment to the quadrate bones posteriorly, which evidently send processes forward and inward so as to meet backward processes of the pterygoid. There is no articular condyle to the quadrate bone; but the articular surface appears to have been slightly concave. The palatal space between the condyles is concave; but the condyles themselves do not seem to have been prominently developed. The malar bar is preserved on the right side of the specimen only; but its condition does not show sutures, and therefore gives no evidence of the quadrato-jugal. The occipi-

tal condyle is small and globular. On each side of it there is a strong lateral bony mass as big as the condyle itself, but separated by an inferior groove, as is often seen in the basioccipital bone of Plesiosaurs.

The way in which this skull diverges from *Plesiosaurus* or *Nothosaurus*, suggests a distinct approximation to Lizards. And there are many lizards in which the palate might, by a median blending of the pterygoid bones, present a similar aspect.

An approximation to such a palate is offered by the common *Lacerta agilis*, though the superior surfaces of the two skulls are not likely to show any thing in common. The distinctive feature of the lizard palate consists in the presence of the vacuities which result from the pterygoid bones abutting against anterior angles of the sphenoid, so that they do not completely meet in the middle line. Even in *Amphisbæna* the structure of the palate, with the pterygoids external to the basisphenoid, is hardly an exception to the Lizard plan, though the pterygo-sphenoid vacuities are so far reduced as to make the palate essentially Chelonian. It is therefore probable that the Lizard-like conformation in this fossil, is not indicative of Lacertilian affinities, at least of affinity towards any surviving type of the group. It is at first sight as difficult to see any resemblance in it to the Plesiosaur as to distinguish it from the Lizard; for the backward position of the external nares towards the middle of the head in Plesiosaurs necessarily gives rise to a difference of proportion in the palatal regions, and causes the posterior nares to be carried backward so as to approximate to the Crocodilian plan (see Owen, Monog. iii. Rept. Kim. Clay, t. i. fig. 1, also Rept. of Lias, t. xvi.). But if the premaxillary bones had not extended their posterior margins backward so as to remove the external nares from the extremity of the snout, then probably the palate of *Plesiosaurus* would have compared better with our fossil; for the lateral vacuities in the palate might then have held a more forward position. But in any case *Plesiosaurus* has no representative of the vacuities which occupy the middle of the palate, and are margined posteriorly by the transverse bones, any more than has *Nothosaurus* or *Simosaurus*, in both of which the palatal nares are as far forward.

Vertebral Column.

The neck (Pl. XIII. fig. 1) is twice or twice and a half as long as the head. It includes about 20 vertebræ; but the state of preservation is such as to present considerable difficulty in determining which should be taken as the last cervical; and it may be that some would prefer to count only 17 vertebræ. The length of the cervical vertebræ appears to vary but little, though the centrums increase in size as they recede from the head and approach the back. The cervical region, however, is not so well preserved as to show the exact form of the bones. There is no clear evidence of the form and characters of the articular face of the centrum; in the lower part of the neck the base of the centrum appears to be grooved. I am unable to recognize any cervical ribs

such as are found in the anterior part of the neck in *Plesiosaurus*; but after the 17th, where the vertebræ became wider, ribs are preserved. Each vertebra is about 3 mm. long. The rib is about 5 or 6 mm. long, and tapers to a point. It is impossible to adopt the same mode of classifying the regions of the vertebral column as is in use with Plesiosaurs; for although the first four or five vertebræ with ribs probably have the stout expanded head of the rib supported partly on the centrum and partly on the neural arch, there is no evidence that this is the case; and therefore, though I should be disposed to regard these vertebræ as pectoral, other writers might group them with the neck, because they are anterior to the scapular region, or with the back, because they bear ribs.

The cervical vertebræ do not lie quite undisturbed; the atlas and axis appear to be broken; the third vertebra exposes the articular end, showing the neural canal to be higher than wide, with the posterior articular face of the centrum flattened, but slightly convex from above downward. The upper table of the neural arch extends back a little beyond the neurapophyses, and extends outward a little beyond them. The sixth vertebra, which lies on its side, has a distinct tubercle for the rib, on the lower part of the centrum; and the fifth shows a median ridge on the base of the centrum, with a groove on each side of it. The middle cervical vertebræ have lost their neural arches, and there only remain the facets to which arches were attached. These facets are ovate, placed towards the anterior part of the centrum, and separated from each other by a considerable interval, so that the spinal cord rested upon the centrum. The neural arches are better seen in the second specimen (Pl. XIII. fig. 3), in which, however, only seven cervical and three or four pectoral vertebræ appear to be indicated with certainty. Only the dorsal aspect of the neural arch is there shown. It is remarkable in character, because there is no neural spine, the neural spine being only represented by a slight ridge, unless, indeed, it should have been broken away in excavating the specimen, of which I am unable to detect any certain evidence under the magnifying-glass. This slight ridge is, moreover, prolonged forward as a blunt conical spine, which overlaps and apparently articulates with the neural arch of the vertebra in front. On each side of this ridge the upper surface of the neural arch is rounded, somewhat oblique, and forms remarkable zygapophyses, the zygapophysial facets being unusually large both in front and behind. In front they are completely divided by the median ridge; they are directed horizontally, and form an unusually compact connexion in the neck.

In the principal slab (Pl. XIII. fig. 1) the dorsal vertebræ all lie on their sides. In the lower part of the dorsal region they are covered by the thin bones of the pelvic girdle, so that it is difficult to count the exact number. Including the pectoral vertebræ, there are, however, 29 vertebræ in the back, reckoning the last dorsal to be in a line with the ischio-pubic suture.

The second specimen, however, cannot count more than 26 vertebræ in the same limits; there is therefore some reason for

supposing that we may have here to do with a second species, a suggestion which is supported by some characters of the tail and the smaller bones of the limbs. If distinct, however, the specimens are so closely allied that I feel justified in quoting the characters of one as illustrative of the other.

In nearly all Plesiosaurs the dorsal rib is supported upon a more or less developed tubercle or transverse process. This type, however, shows *no trace of any such character*. Each centrum is 4 mm. long; the body of the centrum is rounded; and instead of there being a constriction between the two articular ends, the centrum is slightly inflated in the middle so as to approximate to a barrel-like form. Above the centrum is the neural arch, generally to be recognized by its suture; and at the base of the neural arch, where it expands a little, is the articulation for the rib. And while the rib is single-headed as in *Plesiosaurus*, the ribs themselves have a Crocodilian aspect, because, articulating at the base of the neural arch, the slight transverse tubercle indents or notches them out above. The neural arch is less high than the centrum; it is oblong, and nearly as long as the centrum. Where there is a slight displacement in the series the articular end of the centrum appears to be flat. In the region of the shoulder-girdle several centrums appear united together (Pl. XIII. fig. 1). The second and smaller animal only exhibits the neural aspects of the vertebræ (Pl. XIII. fig. 3). The sides are divided by the median longitudinal ridge indicative of the neural spine, which may be a trifle broader than in the neck. The lateral parts of the neural arch are transversely expanded and somewhat rounded; each neural surface is once and a half as wide as long, has its anterior margin slightly convex, its posterior margin concave, its lateral margins straight. The ridge of the neural spine appears to be prolonged between the zygapophyses, though to a less extent than in the neck. There is no sacrum formed by union of vertebræ, and no vertebra that can be recognized as sacral from any modification of structure that it presents. The vertebra, however, immediately behind the ischio-pubic suture should be counted sacral; and then in the larger specimen there would seem to be 15 caudal vertebræ. At least 13 caudal vertebræ are preserved in the smaller specimen; but they correspond in form and size to the first 8 in the larger specimen, and obviously are only a portion of the tail. This, with some differences in the length of the vertebræ, would again suggest that the specimens may belong to two species.

In the larger individual the tail is only presented on one side, and it has been developed so as to show the transverse processes. The second centrum behind the ischiac bones is 7 mm. long. The transverse process arises from the front part of the centrum, and is broad, compressed, and strong; but these processes become rapidly smaller and soon disappear.

The length of the tail, as preserved, reckoning to the back of the sacral vertebra, is only 45 mm.; and although it may have extended further there is no proof or, indeed, reason to suspect that the length would have exceeded 5 cm. In the second specimen the

tail, as preserved, is 5 cm. long, but shows no indication of being near the end where it terminates. In this length the vertebræ are compressed from side to side, and have the transverse processes less robust than in the larger specimen. The processes become shorter, and in the last 3 or 4 vertebræ are only indicated by tubercles. Hence in the larger or type specimen the vertebral formula appears to be 17 cervical, 29 dorsal, 1 sacral, and 15 caudal.

The Ribs.

The large specimen (Pl. XIII. fig. 1) has the ribs spread out on each side of the vertebral column symmetrically and in natural position, except for a slight displacement on the right side of the body in the pectoral region. Seven vertebræ anterior to the humerus have ribs; the first of these may belong to the cervical region. The next four may also belong to the neck, but the two immediately in front of the humerus are probably to be counted as dorsal. Reckoning in this way, there are 22 or 23 pairs of ribs with corresponding vertebræ anterior to the pubis, all of which must be reckoned as dorsal. The length of this region is about 98 mm. The width across the ribs and vertebral column as they lie is 34 mm. in the middle, narrowing a little towards the anterior and posterior ends, owing to the ribs becoming somewhat shorter. The ribs are curved; measured from end to end without regarding the curve, they are about 2 cm. long. Cylindrical in the abdominal two thirds, they are expanded, thickened, and enlarged towards the articulation with the vertebra. The thickening appears to have been greatest from above downward; and, as already remarked, there is a sort of notch at the articular end, different from what is observed in any Plesiosaur, and highly suggestive of a double articulation, though not inconsistent with the Lizard type. No specimen shows the articular facet, but the corresponding facet on the neural arch always exhibits a pit.

In the smaller specimen (Pl. XIII. fig. 3) the ribs are more nearly in natural position, but their distal ends are crushed together so as to be absolutely in contact. The principal bones of the pelvis and of the scapular arch are hidden; but I do not think more than 22 pairs of ribs could properly be reckoned as dorsal. The proximal ends of the ribs appear to be relatively larger and more cylindrical than in the other specimen, and the interspaces between the ribs appear to be less, though in no case is the interspace equal to the width of the rib itself, as they lie. The transverse width across the ribs in the small specimen is little more than 2 cm.

In the remarkable elongation of the neck and proportions of the vertebral column, the characters are entirely Plesiosaurian; but, for a member of this group, the intercentral surfaces are remarkably flat; and unless the apparent blending of the early dorsal centrums in the region of the coracoids is an accidental character, it makes a marked difference from known Plesiosaurians. The appearance of pegging together in the neural arch has, at first sight, a suggestion of the mode of union of the neural arches of certain Lizards and

Ophidians; but there is no reason to regard it as an evidence of affinity. Similarly the long neck recalls the lizard from the Chalk named *Dolichosaurus,* which also has the arches joined by zygosphene and zygantrum. And in the rib rising directly from the side of the vertebra in our fossil, without transverse processes to support it, the character is more Lacertian than in *Plesiosaurus.* But it should also be remembered, that *Pliosaurus*, and *Rhomaleosaurus* from the Lias, like *Nothosaurus*, have the cervical ribs articulated by double heads, as in Crocodiles; so that much weight cannot be attached to characters in which the vertebral column shows Lacertilian analogies.

The Pectoral Arch

is imperfectly preserved (Pl. XIII. fig. 1). The coracoid on the left side is entirely removed; on the right side it is complete. It has very much the form of an ischium of *Plesiosaurus,* and is as unlike the coracoid of Plesiosaurs as could be while still formed on the same plan. The bones were directed backward, and met in the median line by a suture which was not more than 7 mm. long. The oblique position of the coracoid will be best understood by stating that the median suture is entirely posterior to the glenoid cavity for the humerus. The transverse width of the bone is about 12 mm. Its extreme length, measured obliquely, is about 14 mm. It is constricted in the middle; but the anterior concavity is shorter and deeper than the posterior concavity. The width at the scapular end is less than 7 mm., and the corresponding antero-posterior measurement at the median suture is more than 8 mm. At the suture with the other coracoid there is a small wedge-shaped interval at the posterior margin, such as is usually seen in Plesiosaurs. The scapular end has a small anterior surface for union with the scapula, and a wider, thicker antero-lateral surface for union with the humerus. In transverse measurement the bone is concave, while from front to back it is flattened. The scapulæ are imperfect; but that on the left side is the better preserved. It has somewhat of a chopper-like shape, the part which would correspond to the handle of the chopper being directed above the head of the humerus, much like the suprahumeral process of the scapula in *Plesiosaurus.* The blade of the bone is subobovate, with a slight median ridge dividing the surface into two nearly equal portions. This ridge terminates posteriorly in a thickened, rounded articulation, which contributed with the coracoid to form the glenoid cavity for the humerus. Interior to this, though not well seen, is the articular surface which unites the bone with the coracoid. The ridge on the bone not improbably indicates the area which was overlapped by the clavicle. The length of the blade of the scapula is just over 1 cm.; its breadth is 6 mm.; the length of the posterior process cannot be given with certainty, since it is partly covered by the head of the humerus; but it could not have been less than 3 mm. This process ascends at a considerable angle above the plane of the base of the bone. As already remarked, the

bone is convex from side to side, owing to the ridge; it is slightly concave in length.

In the second specimen the coracoids are not seen, and the scapulæ, looked at from above, present no resemblance to the bones just described. How far this apparent difference may be due to position, and how far to their being covered by the clavicular bones, I am unable to determine. The posterior processes are parallel to each other; and the transverse external width across them is 2 cm. The length of the scapula appears to be about $13\frac{1}{2}$ mm.; but the posterior process is not quite complete behind, where it extends over the head of the humerus and the articular part of the coracoid. The scapulæ appear to converge forward in a convex curve.

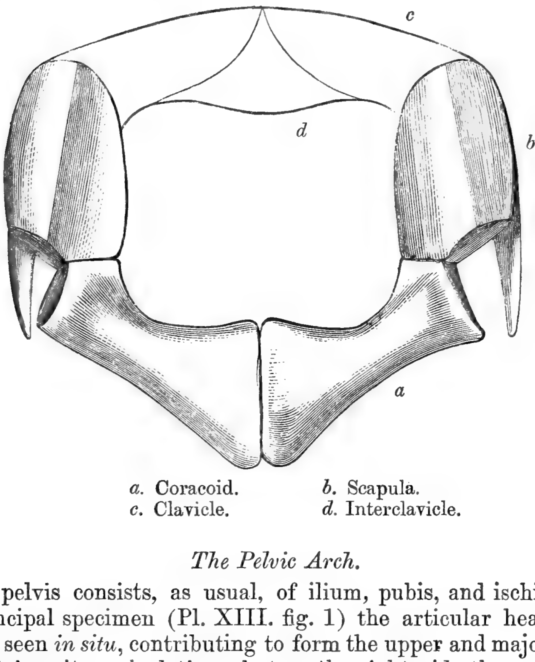
The coracoid is essentially the same in type as that so well figured by von Meyer as pertaining to *Nothosaurus*. The scapula only differs in specific characters and smaller size from some small bones (Muschelkalksaurier, t. 33. fig. 40–44) found near Jena, which von Meyer did not name. It has a general resemblance to the scapula of *Nothosaurus* (t. 34). The fragment of a left clavicle which adjoins the corresponding scapula is broad, but too imperfect to give any idea of the nature of the clavicular elements of the arch. Thus the pectoral bones, as a whole, are much more like those of *Nothosaurus* than *Plesiosaurus*. The Nothosaurian coracoid is essentially a modified crocodilian coracoid, differing chiefly in having the median margin rather more elongated; and instead of having the articular end of the bone pierced by a foramen, there is a notch between it and the scapula, as in many Dinosaurs and Ichthyosaurs; but this notch is not developed in our fossil. It only needs that the antero-posterior elongation of the coracoid of *Neusticosaurus* should be carried further to make it comparable with that of *Plesiosaurus*. Thus the form of that bone in *Plesiosaurus* becomes a modification of a crocodilian type.

The scapula is at first sight more difficult to understand; but when that bone in *Nothosaurus* is compared with the scapula of the Crocodile, the blade of the bone is similarly directed upward and backward, but is not so expanded as in the Crocodile, while the anterior or preacetabular part of the bone is more developed. The resemblance is not so close as in the coracoid; but the difference is one of proportion, not of plan, and therefore may be classed as functional. In our fossil the blade of the bone becomes directed more backward and assumes a form closely approaching the supra-acetabular process of the scapula in some Plesiosaurs, which I am thus led to identify with the blade of the scapula in the Crocodile. The preacetabular part of the scapula in *Nothosaurus*, or even in this fossil, diverges much less from the crocodilian type than does the scapula of such a genus as *Colymbosaurus* from that of *Nothosaurus*.

The striking and distinctive feature of these Triassic Saurians consists in the great development of the clavicular bones, which form an arch in front of the preacetabular elements of the scapulæ. Nothing corresponding to these elements, except the interclavicular

bone, is known to exist in any Crocodile. In Plesiosaurs, however, the clavicles have become small or absent, and blended with the greatly enlarged interclavicle in those species in which they have been observed; so that in this respect the clavicular region in *Plesiosaurus* is rather more like that of the Crocodile than is that of *Nothosaurus*. The resemblance, however, cannot be pressed, because in *Plesiosaurus* the interclavicle connects the scapulæ together, and braces both of those bones to the coracoids. But we are justified in inferring that, with the diminution of the anterior expansion of the scapula in Crocodiles, the clavicle became lost.

Fig. 1.—*Restoration of the Pectoral Arch of* Neusticosaurus *(external aspect).*



a. Coracoid. *b.* Scapula.
c. Clavicle. *d.* Interclavicle.

The Pelvic Arch.

The pelvis consists, as usual, of ilium, pubis, and ischium. In the principal specimen (Pl. XIII. fig. 1) the articular head of the ilium is seen *in situ*, contributing to form the upper and major portion of the tripartite articulation; but on the right side the acetabulum is broken away; so that I can only mention that the head of the ilium is rhomboid, 4 mm. wide, and 5 mm. deep. The pubic and ischiac bones meet by suture in the median line, and extend over 4 or 5 vertebræ. The length of the pelvic region, formed by these two bones is about 2 cm. The bones are expanded and thin, and closely resemble the corresponding elements in *Plesiosaurus*. The transverse measurement across the pubic bones, as preserved, is 23 mm.; but there seems to have been a slight displacement on the left side, by which the antero-posterior measurement of the bone has become less than on the right side. Each bone is subqua-

drate; it met its fellow in the median line, though the suture cannot be distinguished; it also met the ischium behind in the median line, and on each side of this union the posterior margin is concavely excavated to contribute to the formation of the transversely ovate ischio-pubic vacuity. In front there appears to have been a concave notch between the united pubic bones, about as wide as the base of the centrum; and then each sent forward a short anterior process or prepubic element. External to this, the anterior margin has a deep semiovate concavity. The external margin consists of two nearly equal parts, an anterior oblique area, directed outward and forward, with the margin sharp, and a posterior thickened articulation. The length of this external side of the pubis is about 8 mm. Just behind the articulation is a slight narrow notch opposite to the head of the ischium. The ischium is even more Plesiosaurian; it is directed obliquely backward, and extends in length as it passes inward towards the median line. The articular end is greatly thickened and extends outward rather further than the pubis, showing that the acetabulum was chiefly formed by the ilium and ischium. The anterior margin of the bone is concave, with a deeper excavation than is seen on the longer lateral margin. The bones diverged a little behind from imperfect ossification, like the ischiac elements in *Plesiosaurus*. In the pelvic bones there is a considerable departure from the crocodilian type. The ilium is not separated from the matrix in these specimens of *Neusticosaurus*; but in *Nothosaurus*, in which it was evidently similar, the bone has no trace of that vertical elongation seen in all true Plesiosaurs, but is short, and broad, and thick, and as much suggestive of the Crocodile as an ilium can be which is only attached to one vertebra. But though the bone is not distinctly crocodilian, it is only with the ilium of Crocodiles that it can be compared.

The ischium is larger than that of the Crocodile, and especially more elongated in the antero-posterior median suture; but in its not possessing the preacetabular process which supports the pubis, there is a fundamental difference. This process, however, does not appear to have existed in the Triassic Crocodiles; and according to Huxley (*Stagonolepis*, p. 32) the acetabulum was formed by union of all three pelvic elements; so that there is no divergence from the crocodilian plan in such a difference from existing Crocodiles as *Neusticosaurus* exhibits.

The pubis is not crocodilian in form, and differs in having a far greater antero-posterior development of the postpubic portion, by which the prepubic process becomes dwarfed. But if von Meyer was right in some of his identifications, it would seem that there is scarcely any difference between the plan of the pubis of *Nothosaurus* and that of the Crocodile, both being expanded towards the median suture, and both constricted near the articular end. As a whole, the pelvis of *Neusticosaurus* is less like the Crocodile pelvis than that of *Nothosaurus*; and as it diverges from *Nothosaurus* it makes an approximation to *Plesiosaurus*.

Fore Limb.

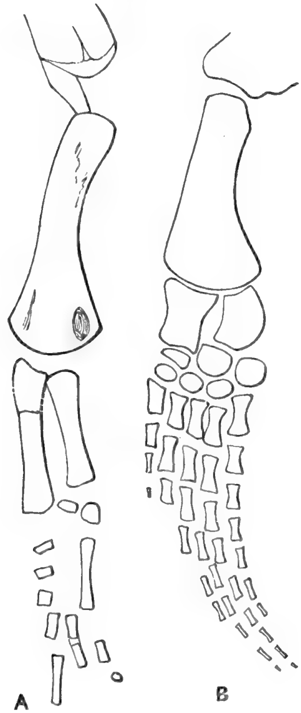
On the left side the fore limb is fairly well preserved (Pl. XIII. fig. 1), though the carpal bones are but slightly indicated, and the phalanges appear to be somewhat scattered. On the right side the humerus is gone, apparently through bad collecting, since there is the cavity in which the bone rested. Ulna and radius are well preserved; but there is only one phalange. On the left side the fore limb is 5 cm. long. The humerus has the shape usual with that bone in *Plesiosaurus*. It is 21 mm. long, 4 mm. wide at the proximal end, $3\frac{1}{2}$ mm. wide in the middle of the shaft, and $7\frac{1}{2}$ mm. wide at the distal end. The proximal part of the shaft is cylindrical, with the articular end rounded, and some muscular roughnesses on the shaft near the proximal end. The lower part of the shaft is more flattened and compressed; near the distal end there is a groove or foramen for a vessel towards the posterior border, as in *Nothosaurus*. The anterior border, in its upper third, exhibits a slight angular bend, such as occurs in some Liassic Plesiosaurs, and is paralleled in the humerus of *Nothosaurus*. The outline of the bone between this angle and the distal end is very slightly concave. The posterior outline is much more concave, owing to the distal end of the bone being expanded posteriorly. The distal articulation is without facets, and is convex from front to back. The ulna and radius are longer and more slender than those of Plesiosaurs, and present a marked transition towards these bones in a Crocodile, though in shortness the forearm rather suggests the Chelonian type. There can be no doubt about the nomenclature of the bones, since they are *in situ*; but from the form alone it might well have been inferred that the anterior bone was the ulna, and the posterior bone the radius. The radius is 12 mm. long. It is imperfect proximally, on the left side; but on the right side the proximal end is seen to be somewhat enlarged and bent inward, with an oblique articular facet to articulate with the humerus; its distal end is more slender; and the bone all together resembles a crocodilian ulna. The ulna on the right side, where best preserved, is 11 mm. long. It is also wider proximally than distally, with nearly parallel sides; the proximal end has an oblique facet. Below the ulna are two small carpal bones; but there appear to be two or three more displaced among the digits, so that the structure of the carpus is unknown; but it had a Plesiosaurian character.

The number of digits is uncertain, and there may not have been more than three. Only one metacarpal (5 mm. long) is preserved; and there are two short conical terminal phalanges.

In the second specimen the humeri are exposed, so that the right shows the dorsal, and the left the posterior lateral aspect. The left bone is not quite perfect distally, and is fractured in three places. The right humerus is fully 18 mm. long; its proximal end is narrower above than below, and is thicker than wide; the distal end is $6\frac{1}{2}$ mm. wide; the anterior margin is convex in outline proximally, concave distally; the distal end does not appear to be quite so much

expanded as in the other specimen; and there is a distinct thickening of the shaft in a blunt ridge near the distal articulation, towards its middle. The radius is 11 mm. long. No digits are preserved.

Fig. 2.—*Comparison of Fore Limbs of* Neusticosaurus *and* Plesiosaurus.



A. *Neusticosaurus pusillus.*
B. *Plesiosaurus Hawkinsii.*

The fore limb at first sight suggests nothing but a modified Plesiosaurian, in which the forearm is relatively more elongated, and the digital bones are fewer than in known forms. These are differences such as are well known in certain genera among the Cetacea. But when we compare the bones of the fore limb with those which von Meyer has referred to *Nothosaurus*, a marked difference is observed in the humerus; for that bone in *Nothosaurus* has no trace of the Plesiosaurian form, and is essentially the humerus of a land animal. The difference consists chiefly in expansion of the anterior part of the bone towards the distal end. There is the same slight proximal curvature of the head of the bone backward, the same curvature of the posterior margin, the same distal foramen on the hinder margin of the bone. And seeing how growth

is everywhere developed by intermittent pressure and tension, it seems to me that the difference between these two is precisely such as might be expected to result from conditions of existence such as would result from increased leverage of the body being thrown upon the anterior distal end of the humerus, in consequence of the bone being used as a chief organ in progression, in an animal which was adapting itself to aquatic conditions. Further, on the posterior margin of the humerus of *Nothosaurus*, in the upper third, is a process like a trochanter, which is often seen in certain species of *Plesiosaurus*, in the same position though less developed; and this process I regard as a representative of the radial crest, less developed than in the Crocodile, and rotated further backward. We shall seek in vain among existing reptiles for any near analogue of the Nothosaurian humerus; and if the character were isolated in the skeleton, it would be impossible to say whether the slight crocodilian character were an analogy or an affinity.

In Crocodiles and Chelonians, even more than in Lizards, the humerus is more elongated than the forearm; but in *Neusticosaurus* the forearm is relatively shorter even than in the Crocodiles; for while in the Alligator these regions are in the proportion of about 7 to 5, in the fossil the proportion is 10 to 6. But while the segment of the limb is shortened, the bones have the aspect of those of a land animal: the radius is broad at the proximal end, like the radius of *Plesiosaurus*; and the ulna is broad and curved a little, so as to foreshadow the way these bones in *Plesiosaurus* became shortened as they ceased to support the weight of the body, and at the same time increased in width with the increased tension under new conditions of use.

The proportions of the bones of the hand and their number show no striking departure from the terrestrial type, except in the form of the terminal phalanges, which, as being conical, seem to preclude the idea of functional terminal claws, and approximate towards the condition seen in *Plesiosaurus*, though the phalanges were few, and did not give the limb a Plesiosaurian elongation. (See Fig. 2.)

Unfortunately, the limb-bones of *Nothosaurus* have not yet been found in natural association.

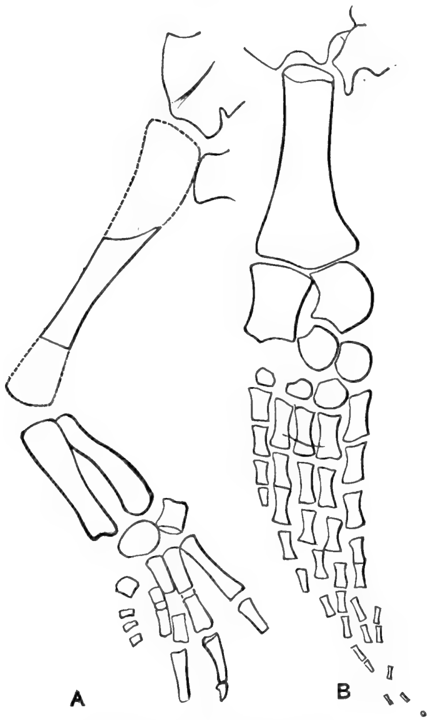
The Hind Limb.

The hind limb is no longer than the fore limb, but of an altogether different character; for while the latter suggests a swimming type, the former is the hind limb of a land animal.

In the type specimen, only the middle of the shaft of the femur is preserved; but the impressions of its extremities in the matrix show it to have been 21 mm. long (Pl. XIII. fig. 1). In the smaller specimen the length is a little less than 20 mm., and the bone appears to be of slightly different form; for in the larger example the impression of the distal end indicates an appreciable widening of the bone, of which there is no trace in the small specimen, which has the distal end more slender than the difference in length would have suggested. But this difference may result from the bone being exposed laterally in the case of the small animal, since in section the shaft of the

larger animal's femur is ovate. The distal end, $1\frac{1}{2}$ mm. thick, is compressed from front to back, flattened inferiorly, with a sharp

Fig. 3.—*Comparison of Hind Limbs of* Neusticosaurus *and* Plesiosaurus.



A. *Neusticosaurus pusillus.*
B. *Plesiosaurus Hawkinsii.*

ridge margining the inferior external border in its distal half; the external side is oblique and rounded distally, and separated by a ridge from the superior aspect of the bone. Proximally the lateral aspect of the bone widens in a wedge shape to 4 mm.; its inferior aspect is flat and forms nearly a right angle with the lateral surface, which is slightly convex; the superior aspect appears to be flattened. There is no indication exposed of an articular condyle to the proximal end, such as might have been expected from a longitudinal ridge running down the underside of the shaft. The tibia and fibula are about 11 mm. long in the larger individual, and 1 mm. less in the small one; and, in harmony with the positions of the skeletons, one exhibits the anterior, the other the posterior aspect of the bones; but both bones are unduly slender in the small specimen. In the larger animal the tibia has a massive appearance: its

proximal end is more than 3 mm. wide; the distal end is fully 2 mm. wide. As the specimen lies, the head of the fibula extends in front of the tibia. The fibula is a characteristic bone, with the external margin straight and the internal margin concave, so that the bone is constricted in the middle and expanded at the two ends.

There are only two tarsal bones—first, a large transversely ovate tarsal placed between the tibia and fibula, and a similar smaller one adjacent to it, and below the fibula. These bones differ in proportions somewhat in the two specimens, but have a close general resemblance to the tarsals of *Plesiosaurus*, in having the lateral surfaces concave, with an elevated margin round the articular edge. The transverse measurement of the large tarsal is 4 mm.

The metatarsal bones and phalanges of the hind limb, like the corresponding bones of the fore limb, in the larger specimen, are badly preserved. The foot was short; but there is no certain evidence whether it included four or five digits. Besides the metatarsal there may not have been more than two phalanges in each digit, though the number probably varied and augmented.

The metatarsals are compressed from side to side, and somewhat enlarged at both ends; in the larger specimen the first is 6 mm. long. Three terminal phalanges are preserved: they are claws of the Lizard pattern, relatively long, compressed from side to side, well hooked, and quite unlike the small terminal conical bones in the fore limb.

In the smaller specimen the metatarsal bones are better preserved. There are four bones placed side by side, and the fractured proximal end of a fifth. There is no divergence between the bones, which increase slightly in length from the first to the fourth. The transverse measurement over these four bones, as preserved, is 6 mm.; the length of the longest is somewhat more. Only one or two fragments of phalanges are preserved, but too imperfect for measurement.

The point of greatest interest in this animal is probably to be found in the diversity of type exhibited by the fore and hind limbs. I am disposed to regard the femur as best comparable to that of the Triassic Crocodilia, in which the bone is straighter than in existing types, and more widened at the proximal end. The divergence, however, is so great that intervening types would be required to justify a detailed comparison; and in this matter *Nothosaurus* gives but little help. The remarkable compressed claws are not crocodilian, but suggest certain Lizards and various extinct animals.

Conclusion.

In endeavouring to estimate the value of the various resemblances to Crocodiles which I have attempted to indicate, it must be remembered that in discussing an animal which lived in the beginning of the Secondary period, comparison has had to be made with a type which still exists, and which, therefore, can scarcely give much clue to the actual modifications which its ancestral forms presented in Triassic times. But as the Crocodiles are traced back through the

Teleosaurs and Belodonts there is a nearer approximation of structure towards Plesiosaurs, which may especially be seen in the conformation of the skull, form of the vertebræ, articulation of cervical ribs, and development of transverse processes from the neural arch in the dorsal region, no less than in the conformation of the elements of the pectoral and pelvic girdles. The proportions of the limbs, too, become more those of a Crocodile in such a genus as *Neusticosaurus*; and this genus demonstrates, I think, that the Plesiosauria must have had ancestors which lived entirely upon land, before the limbs came to be used for natation. That those animals were more nearly allied to Crocodiles than to any existing reptilian order, seems to me highly probable.

In such a group, I fancy, we are reaching the parent type of the great subclass of reptiles which von Meyer named PALÆOSAURIA, which I would enlarge, to include Crocodilia, Rhynchocephalia, Chelonia, Ichthyosauria, Plesiosauria, Anomodontia, and Dinosauria, and especially distinguish from the subclass CAINOSAURIA, in which should be comprised the Lacertilia and Ophidia.

While this genus is closely affiliated to the Nothosaurs and their allies, we see in those animals a type rather terrestrial than marine, which, in the bones of the extremities, diverges widely from the true Plesiosaurs. This osteological modification amounts to a subordinal difference; and for this group it may be convenient to use the name Nothosauria, or to adopt von Meyer's name Macrotrachelia, though that term, being equally applicable to *Plesiosaurs*, is not so distinctive.

EXPLANATION OF PLATE XIII.

Fig. 1. Type of *Neusticosaurus pusillus* (Fraas) showing ventral aspect, natural size.

2. Skull of the same specimen, twice natural size.

3. Dorsal aspect of a second specimen of *Neusticosaurus*, natural size.

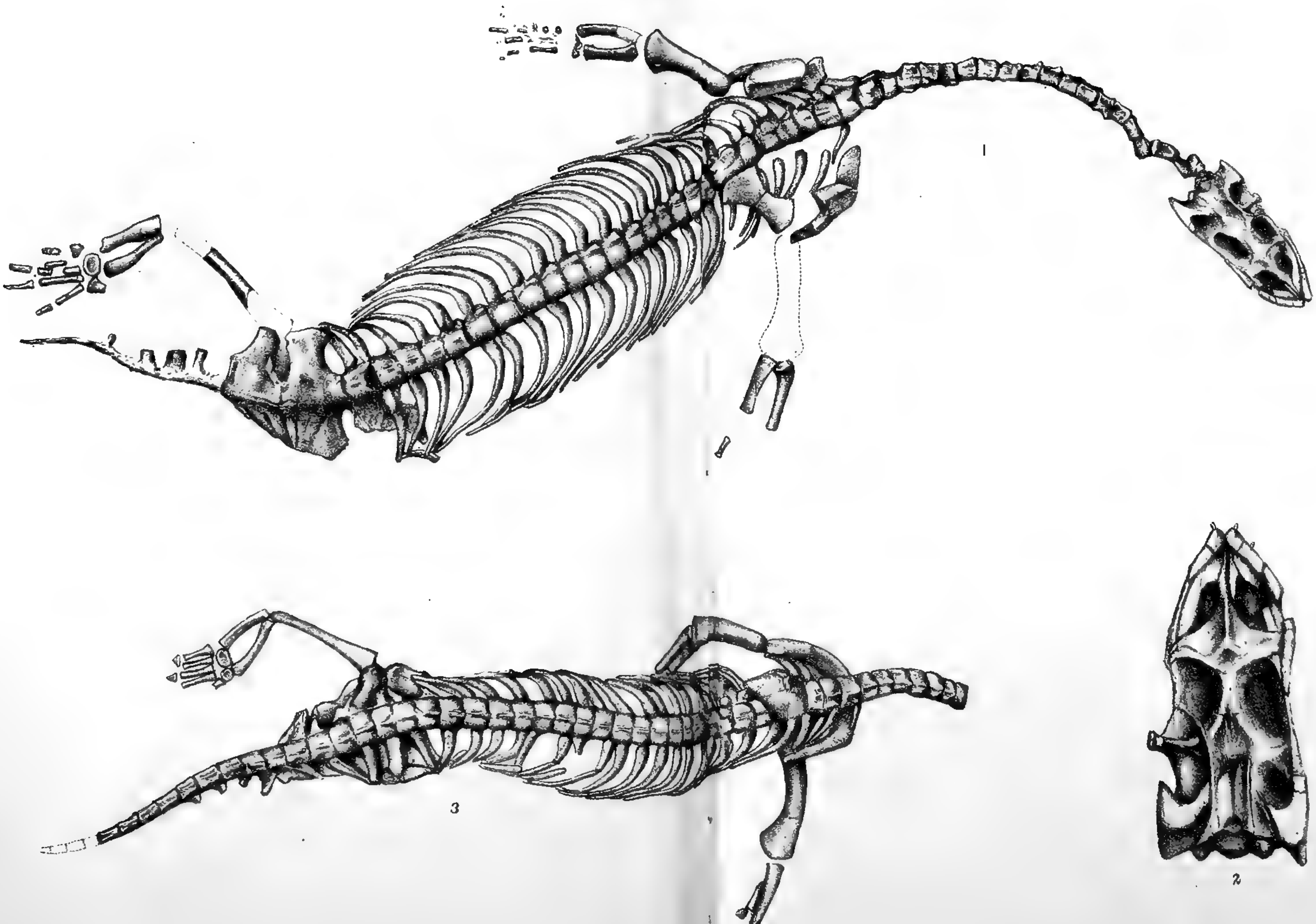
Both examples are in the Natural-History Museum, South Kensington.

DISCUSSION.

Mr. W. A. FORBES pointed out that a similar modification of the anterior and posterior limbs was to be seen in the Penguins. Possibly the anterior and posterior limbs of *Neusticosaurus* may have been used in the same restricted manner as in those birds.

Mr. HULKE spoke highly of the value of the paper; the subject of it was a most remarkable Saurian. The modification described of the fore and hind limbs was very singular; it was very remarkable to find combined in one animal characters which were found in animals so widely separated at the present day.

The AUTHOR agreed with Mr. Forbes that the Penguins presented a parallel instance in some respects.



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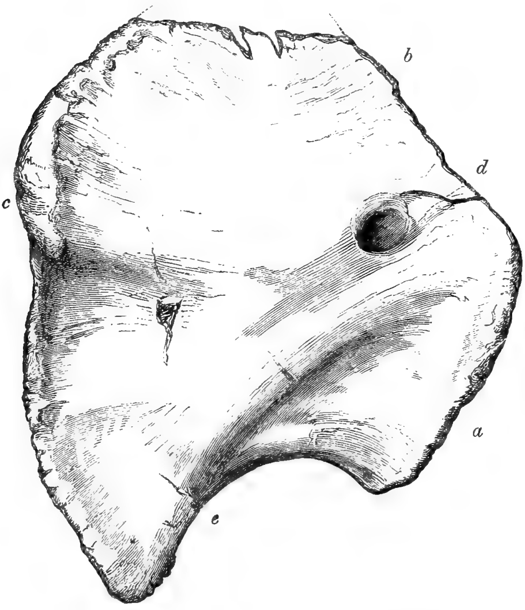
NEUSTICOSAURUS.

37. *On a remarkable* Dinosaurian Coracoid *from the* Wealden *of* Brook *in the* Isle *of* Wight, *preserved in the* Woodwardian Museum *of the* University *of* Cambridge, *probably referable to* Ornithopsis. By H. G. Seeley, Esq., F.R.S., F.G.S., Professor of Geography in King's College, London. (Read May 24, 1882.)

Many years ago (about 1866) Mr. Henry Keeping obtained from the cliff at Brook, midway between the fossil forest at Brook Point and Brook Chine, at about 10 feet above high-water mark, the largest Dinosaurian coracoid which it has been my fortune to examine. It differs in important generic characters from the coracoid of *Iguanodon*; and the only genus hitherto described to which it is likely to belong, is *Ornithopsis*, a Saurian to which Mr. Hulke has already referred many bones of gigantic size.

Fig. 1.—*External View of the Dinosaurian Coracoid, one sixth natural size.*

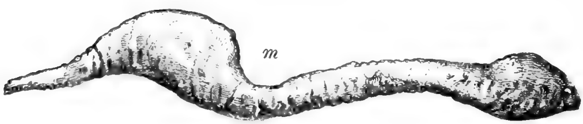


a. Humeral articulation. *b.* Scapular margin.
c. Median thickening. *d.* Coracoid foramen.
e. Termination of inferior ridge.

The specimen is from the right side, and perfect, except that a small portion of the thin anterior margin has been broken away. The external surface of the bone is irregular, but somewhat convex from front to back; the visceral surface is similarly concave. The

bone is of moderate thickness, but greatly expanded at the humeral articulation. Its greatest length is about 44 centim. ($17\frac{1}{3}$ in.); greatest width 36 centim. ($14\frac{1}{4}$ in.); and the greatest (external) length of the humeral articular surface is 20 centim. ($7\frac{9}{10}$ in.), while the greatest (internal) length of the suture for the scapula measures about 27 centim. ($10\frac{2}{3}$ in.) The bone gives no certain evidence of union with a sternum, though the fact that the extreme posterior end of the internal border of the bone is thicker (fig. 2, *r*) than the part which is anterior to it is rather in favour of the possibility of the hinder part of the bone having had such an osseous relation. But the great thickening of the internal or median sutural margin in a line transversely indicating the junction of the coracoid and scapula convinces me that the coracoids there met in the median line, though their union was by no means firm. As a whole, the bone has a curious general resemblance to the anterior portion of an ilium, such as is seen in some of the large American types.

Fig. 2.—*Contour of Median Sutural Margin of Dinosaurian Coracoid.*



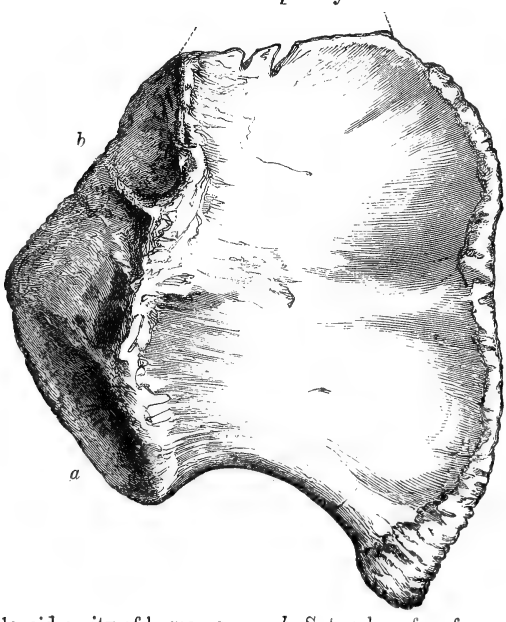
m, contour of external, and *n*, internal surfaces. *p* is placed at the imperfect anterior border. *r*. Posterior border.

The Median Sutural Margin (fig. 2).—Though the lateral outline is convex as a whole from back to front, it is straight or a little concave for a length of about 27 centim. ($10\frac{2}{3}$ in.) in the middle, where the bones may have met; and the diverging posterior margin is also straightened where it may have abutted against a sternum. This surface is convex from within outward, and roughened with transverse grooves, parallel and more or less irregular, indicative of a cartilaginous surface to the bone. The contour of this surface, as seen transversely (fig. 2), is remarkably like that of a ladle with the bowl in front, so that its convexity projects outward and thickens the bone to $5\frac{1}{2}$ centim. ($2\frac{1}{6}$ in.), while, owing to the corresponding though lesser internal concavity, it tapers forward. But immediately behind this anterior thickening the bone is compressed to a thickness of 2 centim. ($\frac{4}{5}$ in.); and here the external surface is concave and the internal surface is convex; then succeeds a longer external curve with a corresponding internal concavity terminating in the posterior expansion of $5\frac{1}{2}$ centim. width already mentioned.

The External Surface (fig. 1).—This is necessarily irregular towards the median line (*c*), with the folds and thickenings of the bone already described, which somewhat resemble those of *Colymbosaurus* and certain Plesiosaurs where these bones meet in the median line. The bone is 18 centim. ($7\frac{1}{10}$ in.) wide proximally, 26 centim. ($10\frac{1}{4}$ in.) wide in the middle where thickest, and from

20 to 21 centim. ($7\frac{9}{10}$ to $8\frac{3}{10}$ in.) wide at the concave posterior border. The extreme length of the external margin is 33 centim. (13 in.), while the internal margin is about 41 centim. ($16\frac{1}{7}$ in.) long. The suture for the scapula, *b*, converges anteriorly somewhat toward the internal sutural margin. The foramen which perforates the coracoid towards its suture with the scapula, *d*, is oval, about 4 centim. ($1\frac{3}{5}$ in.) long by 3 centim. ($1\frac{1}{5}$ in.) wide, situate $3\frac{1}{2}$ centim. ($1\frac{2}{5}$ in.) from the scapular suture, and about 16 centim. ($6\frac{3}{10}$ in.) from the nearest part of the curve of the concave posterior border. The external margin of the foramen is rounded. The perforation pierces into the middle of the scapular suture; anterior to it the bone is undulated; and posteriorly the bone is convex from before backward, and concave towards the elevated margin of the glenoid cavity. At about $7\frac{1}{2}$ centim. (3 in.) behind the coracoid foramen is an oblique deep furrow about 8 centim. ($3\frac{3}{20}$ in.) long, directed backward and inward, but so that if prolonged it would nearly reach the posterior angle of the inner margin, *e*. This groove has in its posterior part the appearance of being muscular, and in its anterior part a vascular aspect; on its inner margin the bone is rounded, and on its posterior margin it is flattened.

Fig. 3.—*Internal or Visceral Aspect of Dinosaurian Coracoid.*



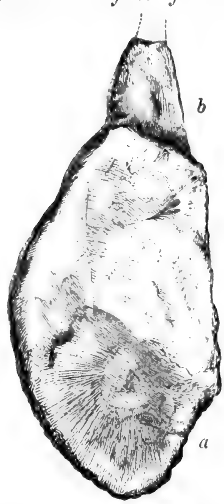
a. Glenoid cavity of humerus. *b.* Sutural surface for scapular.
c. Median margin for union of coracoids.

The internal surface (fig. 3) is moderately concave from within outward; and slightly concave in length, or, rather, is divided into two concavities, of which the larger and deeper is anterior. But

the external articular margin of the bone is straight; the concave posterior margin is rounded from below upward, and maintains a uniform thickness of about $2\frac{1}{2}$ centim. (1 in.).

The external margin (fig. 4) consists of two parts:—a posterior semiovate articulation, *a*; and an anterior subtriangular sutural surface for the scapula, *b*. The latter is about 15 centim. (6 in.) thick, and measures about 17 centim. ($6\frac{3}{4}$ in.) on the line where it meets the glenoid cavity. The external margin is about 17 centim. ($6\frac{3}{4}$ in.) long, and the internal margin is about 27 centim. ($10\frac{2}{3}$ in.) long. Where it terminates anteriorly the bone is about 4 centim. ($1\frac{3}{5}$ in.) thick. The sutural surface is irregular and undulating, but lies essentially in one plane; it is rough with cartilaginous attachment. It is at a right angle with the interior margin of the bone, but makes a sharp angle with the external surface.

Fig. 4.—*Scapulo-glenoid Surface of Dinosaurian Coracoid.*



a. Glenoid cavity of humerus. *b.* Sutural surface for scapula.

The articular surface for the humerus has its outline convex externally (fig. 4); behind the convexity it is sharper; and internally it is straight. The greatest thickness of the bone is a little over 17 centim. ($6\frac{3}{4}$ in.), the greatest length of the surface is 18 centim. ($7\frac{1}{10}$ in.), and its greatest width about 10 centim. (4 in.); the glenoid cavity is gently concave, but towards the outer part shows grooves which indicate that the articular cartilage was not entirely ossified.

Of all coracoids of British Dinosaurs, that which approaches nearest to this type is seen in the skeleton referred to *Hylæosaurus* from the Wealden of Tilgate. But in *Hylæosaurus* the distal portion of the bone is more prolonged, the median portion is less thickened, and the foramen is placed behind the middle of the humeral border far away from the scapular margin. The bone is

distinguished from the coracoid of *Iguanodon* by wanting the notch between the humeral and scapular surfaces, which in that genus represents the foramen in this.

In many characters our Wealden coracoid approaches nearer to American types, such as *Morosaurus*, and especially *Camptonotus*, than to any English form. The resemblance is seen in form of the bone, angle of the scapular margin, and especially in a ridge which diverges from the humeral articulation downward over the outer surface of the bone. This ridge is well seen in *Stegosaurus*, and is less developed and nearer the margin in *Camptonotus*. But in no American genus are the characters identical with those here seen; for in this coracoid the lateral ridge rises opposite the middle of the humeral articular surface.

The large size of the bone makes it probable that the bone, if pertaining to a described genus, must be referred to either *Pelorosaurus* or *Ornithopsis*. The resemblances of the bone to coracoids of American Stegosauria may make the affinity of the bone with *Ornithopsis* sufficiently probable to be adopted. *Pelorosaurus* has never been critically described; but many of the bones referred to it seem to me unquestionably Iguanodont, probably belonging to a large species of *Iguanodon*; while other bones like the great humerus (Owen, Palæont. Soc. 1859, Suppl. 2, p. 39, pl. xii.) seem to me to belong to *Ornithopsis*.

So few types of Dinosaurian coracoid have been figured, that I believe this form will possess a certain interest in demonstrating that generic characters may be found in the shoulder-girdle; and it may furnish new evidence in support of the genus *Ornithopsis*.

I would express my thanks to Professor Hughes for his kindness in allowing me to study this specimen.

Discussion.

The President considered the specimen the most magnificent Dinosaurian coracoid he had ever seen. There was one thing to be said against regarding this bone as belonging to *Ornithopsis*, namely that it had been found in beds lower than those in which *Ornithopsis* had hitherto been obtained. He doubted whether there had been any mesial sutural union of the coracoids, a feature as yet unobserved in Dinosaurs. *Iguanodon Seelyi* was found at the same horizon as this bone.

Prof. Seeley did not see any difficulty in *Ornithopsis* occurring lower in the beds at Brook, since it ranged to Tilgate. He was at first disposed to examine whether this coracoid might not belong to *Pelorosaurus*. But most of the bones of that genus so resembled *Iguanodon* that there are no characters in the coracoid or other parts of the skeleton which differentiate it clearly. If the bone is attributed to *Iguanodon Seelyi*, it proves that that species must be referred to some other genus; for the characters of this coracoid are distinct from those of *Iguanodon*. The reference of an isolated bone to its species when the region to which it belongs is previously unknown is necessarily a matter of probabilities.

38. *Note on the* Os Pubis *and* Ischium *of* Ornithopsis eucamerotus*.

By J. W. Hulke, Esq., F.R.S., F.G.S. (Read March 22, 1882.)

[Plate XIV.]

In four communications on remains of this remarkable aberrant form of Dinosaur which the Society has published in its Quarterly Journal, I have described and figured its cervical and thoracic vertebræ, and noticed the affinity which these suggest with *Ceteosaurus oxoniensis*, and also with certain North-American Dinosaurs described by Profs. O. C. Marsh and Cope†. At the date of my last communication (1879), I was unable to lay before the Society any information respecting the vertebræ behind the thorax, or the girdle- and limb-bones. None of these had been found by Mr. Fox or myself in such close association with vertebræ of the forms I described as to demonstrate that they were parts of one skeleton; and in the absence of this, the expectation that the posterior vertebræ and the other bones should exhibit a textural and constructive agreement with the vertebræ known to us constituted during several years an insuperable obstacle to their identification.

The removal of this prejudice we owe to the recovery in Colorado of a large series of remains of allied forms, in excellent preservation, which demonstrate in the posterior vertebræ the absence of the side pits and chambers that are so conspicuous a feature in the cervical and thoracic centra, and the solidity of the posterior centra, as also of the girdle- and limb-bones‡.

The figures already published by Profs. O. C. Marsh and Cope have confirmed an identification that I made in 1873 of three bones then recently acquired by the late Rev. W. Fox; and they enable me now to make another step in the reconstruction of *Ornithopsis*. These bones, lately purchased as part of the Fox Collection by the British Museum, were bought by Mr. Fox with several of his finest typical thoracic vertebræ of *Ornithopsis*, and a couple of other vertebræ, which, considering them Ceteosaurian, he threw aside, as he never placed any value on these. Two of these bones appeared to me to be unmistakably ischia, and the third a pubis. Mr. Fox permitted me to take a rough sketch of them; but for a long time he would not allow their complete extrication from the rock, nor the readjustment

* Synonyms: *Eucamerotus*, Hulke; *Bothriospondylus* (in part), R. Owen; *Chondrosteosaurus*, R. Owen.

† Its affinity with *Camarosaurus*, Cope, was discussed by Prof. R. Owen in a paper in the Ann. & Mag. Nat. Hist. Sept. 1878, " Restoration of *Chondrosteosaurus*," the name substituted for *Bothriospondylus*, under which he had previously described (Pal. Soc. Mem. 1875–1876) some vertebral remains in the British Museum, including the centra (nos. 2239, 28362) upon which, in 1869, Prof. Seeley had founded the genus *Ornithopsis*.

‡ Prof. O. C. Marsh writes to me, under date Dec. 24, 1881, that he had nearly completed a memoir on these Sauropoda, illustrated by 90 quarto plates.

of the many fragments into which they were broken. This has now been accomplished by the skilful mason of the national museum, under the instruction of Mr. Davies, who has succeeded beyond my expectation in joining together these valuable relics.

The *Os Pubis* (Pl. XIV. fig. 1, *P*) is an oblong flattened bar 73 centim. ($28\frac{6}{8}$ in.) long, with a breadth of 28·6 centim. ($11\frac{3}{8}$ in.) and 27·5 centim. ($10\frac{7}{8}$ in.) at its proximal and distal ends, and of 23 centim. ($9\frac{1}{8}$ in.) at its middle, where, however, the posterior border is mutilated. The proximal end is divided into two parts. Of these, the posterior, 10·1 centim. (4 in.) long by 5·5 centim. ($2\frac{1}{8}$ in.) wide, is an arc of a large circle; it is smooth, and evidently formed part of the circumference of the acetabulum. The other part of the proximal end, anterior in position to that just described, is 19 centim. ($7\frac{1}{8}$ in.) long, and 7·5 centim. (3 in.) wide at its middle, from which its width decreases forwards to the angle where the end meets the anterior border of the bone; this part, now somewhat damaged, was evidently united to the pubic process of the ilium. The anterior border, fortunately entire, stouter than the posterior, is slightly incurved near the ends, and intermediately throughout nearly its whole length almost straight. The posterior border, for a space of 20·3 centim. (8 in.) from the obtuse angle it makes with the upper end of the bone, is nearly straight, and throughout this extent it articulates with the ischium. Below this articular portion the remainder of the border, non-articular, takes first a deep incurve, and then curves outwards with the widening of the bone at its distal end. This strong incurve of the border between the two ends appears to have been interrupted at its middle by a slight projection, where also is a slight inflexion of the border towards the interior of the pelvis. The exact form of this part is no further ascertainable, some pieces having been broken off and lost. The distal end of the bone, now 27·5 centim. ($10\frac{7}{8}$ in.) across, was originally wider, as the posterior angle is mutilated. It is stout, being at the middle 9 centim. ($3\frac{1}{2}$ in.) thick; and inferiorly, and on its inner aspect, it has the roughness indicative of a symphysial union with its fellow bone of the other side of the pelvis.

An oval foramen, 8·3 centim. ($3\frac{2}{8}$ in.) in its long diameter, pierces the pubis near its upper end in the angle included by the acetabular and ischiatic margins.

The *Ischium* (Pl. XIV. fig. 1, *Is.*) is a narrower, stouter, and more curved bar than the os pubis, than which it is also shorter, a straight line joining its extreme points measuring 65 centim. ($25\frac{5}{8}$ in.). Its greatest breadth nearly in the mid-level of the pubic articulation is 19 centim. ($7\frac{1}{8}$ in.), its distal end is 17·7 centim. (7 in.) wide, and the middle is its narrowest part, being somewhat more than 10 centim. ($3\frac{1}{2}$ in.) across. Its upper end, like that of the os pubis, consists of two parts. Of these, the posterior, very stout, rises high above the other. It has a rudely oval sectional outline 14 and 7·7 centim. ($5\frac{4}{8}$ and $2\frac{6}{8}$ in.) in its two diameters; and its surface has a roughness which plainly speaks of its junction with the ilium. The other part of this end lying in front of that just described is a curved, smooth

surface, plainly acetabular. It is continuous with the adjoining smooth acetabular part of the os pubis, than which it is slightly wider. The distal end of the ischium is thin, and quite unlike that of the os pubis; it is devoid of indications of symphysial union with its fellow bone of the other side; and since it is nearly perfect it may be regarded as certain that no such union was ever present. The posterior border, stout and rounded, forms a large simple curve from end to end. It is the stoutest part of the bone, attaining its greatest thickness in the iliac process, and decreasing from this towards the distal end. The anterior border, much less stout than the posterior, has near the acetabular end a flat straight surface by which it was connected with the os pubis. In the rest of its extent it is non-articular. A change in the direction of its surfaces towards its ends gives the ischium the illusive appearance of a twist. At the upper end a line drawn across the bone in the direction this is thought to have had in the articulated skeleton would be approximately parallel to the vertebral column, whilst a second line drawn across the surface near the lower or distal end of the bone would cut the first line at a small angle.

The cortical bony tissue of the os pubis and ischium is compact, and its external surface is smooth; but these characters are much less pronounced than in the chambered thoracic and cervical vertebræ, and the cancellous tissue makes no approach to the megacellular texture so conspicuous in them.

A moment's comparison of the side views of the pelves of *Iguanodon** and *Ornithopsis* (Pl. XIV. fig. 1) will suffice to show how widely different are the form and arrangement of the constituent bones of the os innominatum. In *Iguanodon* the ischium and the long, slender, rod-like part of the os pubis (post-pubis as Prof. O. C. Marsh terms it), which is the homologue of the os pubis of *Ornithopsis*, are much more slender than the broad, flattened, plate-like form of the same bones in this latter. In *Iguanodon* they are placed parallel to each other, whereas in *Ornithopsis* their distal ends are widely separated. The ischium of *Ornithopsis* in those respects in which it differs greatly from that of *Iguanodon* roughly resembles that of *Megalosaurus*. It was this resemblance which chiefly guided me in 1873 in my determination of the skeletal position of the bone.

It is, however, in the pelvis of *Ceteosaurus oxoniensis* amongst British Sauropsida that the strongest resemblance to that of *Ornithopsis* is to be found. The similarity of their os pubis and ischium is so evident as to need no comment other than that it is an additional evidence of their affinity, to which in 1871 I called attention upon the evidence of their vertebral remains. But a still closer resemblance is to be found in the pelvis of *Atlantosaurus immanis*. If we exclude some very trivial details, the figure of this given by Prof. O. C. Marsh, in his 'Principal Characters of American Dinosauria,' shows, as regards the os pubis and ischium, an extremely close agreement with those of the Wealden Saurian (Pl. XIV. fig. 2).

In the similarity of the constituents of its haunch-bone to those

* Quart. Journ. Geol. Soc. vol. xxxii. p. 365, fig. 1.

of *Ceteosaurus oxoniensis* and *Atlantosaurus*, *Ornithopsis* departs from the original Dinosaurian scheme as typified by *Iguanodon*, and takes the direction of Lacertilia, in which the postpubic extension, so developed in the os pubis of *Iguanodon*, is absent, and there is no osteally closed obturator foramen. It differs, however, from the Lacertilian haunch-bone in the absence of ischial symphysis, unless I have been deceived on this point; and also from the Crocodilian form notably in the inclusion of the os pubis in the acetabular circle.

These and other associated departures from the typical Dinosaurian patterns have led Prof. O. C. Marsh to place *Atlantosaurus* with other of the newly discovered Colorado Sauria in a special suborder of Dinosauria, the Sauropoda, in which *Ornithopsis* clearly finds its proper place.

Postscript.

For reasons stated in a former paper I adhere to the prior generic name *Ornithopsis*, given by Prof. H. G. Seeley; and since this genus was founded on two vertebral centra (Nos. 2239, 28362, Brit. Mus. Catal.) which there are grounds for referring to distinct species, I adopt *Eucamerotus* as the specific name of the subject of this note, and reserve the specific name *Hulkei*, given by Prof. Seeley, for the Saurian indicated by the fossil No. 2239. The annexed list contains all the references I can find to papers giving descriptions of fossils referable to this genus.

List of Papers on Ornithopsis.

1. Mantell, G. A. Fossils of the British Museum, p. 250. 8vo, London, 1851.
   (Notice of no. 2239 fossil in Brit. Mus., regarded by author as tympanic of *Iguanodon.*)
2. Mantell, G. A. Geology of S.E. of England, pp. 305–306, pl. ii. fig. 5.
   (Notice of same fossil.)
3. Owen, R. Report on British Fossil Reptilia in Reports of Brit. Assoc., vol. for 1841, p. 124.
4. Owen, R. Monograph of Foss. Rept. of Wealden Formation in Pal. Soc. vol. for 1854, p. 18, pl. x.
   (3, 4. Notice of same fossil. The author accepts Mantell's determination, but suggests it may have belonged to *Ceteosaurus* or *Streptospondylus.*)
5. Seeley, H. G. On *Ornithopsis*, a Gigantic Animal of the Pterodactyle kind from the Wealden. Annals & Mag. of Nat. Hist. ser. 4, vol. v. p. 279 (1870).
   (A paper on the fossil no. 2239, recognized by the author as a vertebral centrum, and on another centrum, no. 28362 in Brit. Mus.; read before Camb. Phil. Soc. 22 Nov. 1869.)
6. Hulke, J. W. Note on a new and undescribed Wealden Vertebra. Quart. Journ. Geol. Soc. vol. xxvi. p. 318 (1870).
   (Description of the neural arch of a thoracic vertebra under the name of *Eucamerotus.*)

7. Hulke, J. W. Appendix to above note. *Op. cit.* vol. xxviii. p. 36 (1871).
(*Eucamerotus*, Hulke, identified with *Ornithopsis*, Seeley.)
8. Owen, R. *Bothriospondylus magnus*, Monograph Brit. Foss. Rept. Mesozoic Formation, part ii. pl. viii. Pal. Soc. vol. for year 1875.
(Description and figure of fossil in Brit. Mus. no. 28362).
9. Owen, R. *Chondrosteosaurus magnus*, synonym *Bothriospondylus magnus*. Foss. Rept. Wealden and Purbeck Formations, supp. no. vii. p. 7 (1876).
10. Owen, R. On the Occurrence in North America of Rare Extinct Vertebrates found fragmentarily in England. Part I. Restoration of *Chondrosteosaurus*. Ann. & Mag. Nat. Hist. ser. 5, vol. ii. p. 201, pls. x., xi. (1878).
11. Hulke, J. W. Note (3rd) on *Eucamerotus*, Hulke (*Ornithopsis*, H. G. Seeley). Quart. Journ. Geol. Soc. vol. xxxv. p. 572 (1879).
12. Hulke, J. W. Supplementary Note on the Vertebræ of *Ornithopsis*. Quart. Journ. Geol. Soc. vol. xxxvi. p. 31, pls. iii. iv. (1880).

EXPLANATION OF PLATE XIV.

Fig. 1. Pubis and Ischium of *Ornithopsis eucamerotus*, one fourth nat. size. *P.* Os pubis: *ac*, its acetabular part; *il*, its iliac part; *f*, foramen; *v*, its dilated ventral symphysial end. *Is.* Ischium: the letters indicate the same parts as do the corresponding letters in the pubis.

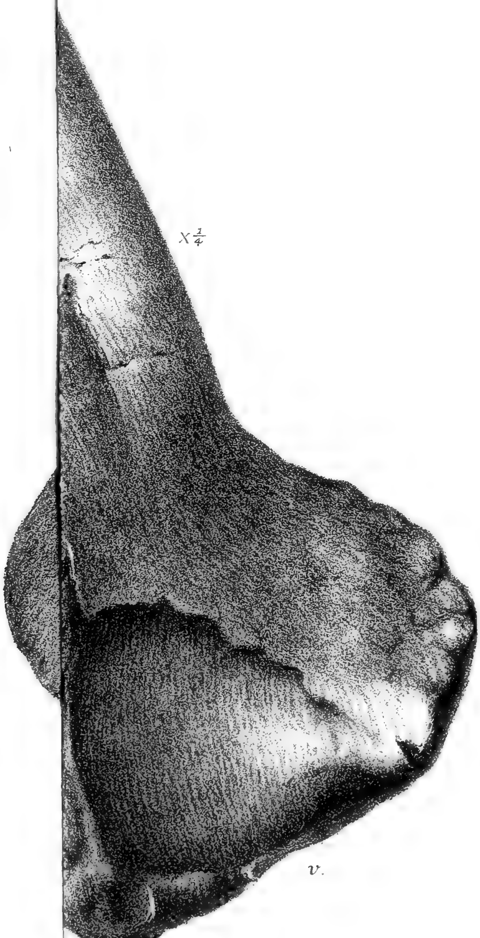
2. Pubis of *Atlantosaurus immanis*, O. C. Marsh, one twentieth natural size. *Il.* Ilium. *P.* Pubis. *Is.* Ischium. (Copied, reversed, from the 'American Journal of Science and Arts,' ser. 3, vol. xvii. pl. vii. fig. 2.)

Discussion.

Prof. Seeley asked for the evidence on which these bones were referred to *Ornithopsis*. He agreed with the author as to the similarity of this and certain American forms, and also as to their affinities with other reptilian types. He thought the evidence should have been given on which it was proposed to separate into two species the two vertebræ which he had first described as belonging to *Ornithopsis Hulkei*, as supposed by Cope and the author, before referring these pelvic bones to either species, supposing them to be distinct.

The Author replied that the pelvic bones were found imbedded in the same block with several vertebræ of *Ornithopsis*. The similar American pelvic bones were associated with vertebræ wonderfully like those of *Ornithopsis*. He thought that the form and proportions of the two vertebræ in the British Museum, on which the genus was founded, were so different that we are justified in believing them to have belonged to two distinct species.

Quart. Journ. Geol. Soc. Vol. XXXVIII. Pl. XIV.



Mary Hanhart imp.

Mary Suft lith.

Hanhart imp.

ORNITHOPSIS EUCAMEROTUS

39. NOTES *on the* ANNELIDA TUBICOLA *of the* WENLOCK SHALES, *from the* WASHINGS *of* MR. GEORGE MAW, F.G.S. By GEORGE ROBERT VINE, Esq. Communicated by Prof. P. MARTIN DUNCAN, F.R.S., V.P.G.S. (Read June 7, 1882.)

[PLATE XV.]

THE bibliography of this very interesting group of animal remains is comparatively scanty if compared with the literature of some other groups. In his celebrated 'Petrefacten' (1820) Schlotheim founded the genus *Cornulites* for the inclusion of "certain Silurian fossils of somewhat doubtful affinities, but apparently most nearly allied to the tubicolar annelids"*. In the 'Silurian System,' published in 1839, species found in the Upper and Lower Silurian were identified with species described by Schlotheim; and since then authors have referred specimens to either *Tentaculites* or *Cornulites*. In 'Siluria,' and also in the 'Cambridge Catalogue,' Salter rectified somewhat the earlier errors by showing that some at least of the casts of specimens had been referred to as separate species. In his 'British Palæozoic Fossils' M'Coy redefines and limits the species of previous authors; but he adds little to our knowledge of the group generally. It is to Prof. Nicholson, whilst working amongst the American Palæozoic fauna, that we owe the most detailed account of Tubicolar Annelida, and that from material collected by himself. In working over the species which had previously been identified as *Tentaculites* he first saw the necessity of founding new genera for their reception. *Tentaculites* † was redefined and limited, and Prof. Nicholson separated this group from ordinary Tubicolar Annelida; but I am not prepared to say that *Tentaculites* belongs to the Pteropoda. Following, however, the example set by Nicholson, I shall keep them separate, and deal with their structural peculiarities further on. The new genera founded by Nicholson are *Conchicolites* and *Ortonia*.

In Emmons's 'Manual of Geology' (1860), p. 108, a figure is given of *Cornulites arcuatus* as one of the fossils of the Clinton group of rocks possessing characters altogether different from *Cornulites*, and more like *Conchicolites* of Nicholson.

In the 'Catalogue of Cambrian and Silurian Fossils in the School of Mines' Mr. Newton furnishes us with a very poor list of British Silurian species as preserved in the museum in Jermyn Street:—

Caradoc	*Serpulites ceratoides*, Wyatt-Edgell, MS.
Upper Llandovery ..	*Cornulites serpularius*, Schlot.
Wenlock Shale......	" " "
	Serpulites curtus, Salter.
	Spirorbis, sp.
Wenlock Limestone..	*Cornulites serpularius*, Schlot.
	Serpulites perversus, M'Coy.
	Spirorbis Lewisii, Sowerby.

* Nicholson, Amer. Journ. Sci. 1872.
† Amer. Journ. Sci. & Arts, vol. iii. March 1873, p. 204.

Some of these species, with the addition of others, ranged into the Lower and Upper Ludlow, interesting particulars of which are given in the Presidential Address to the Geological Society in 1881 by Mr. Robert Etheridge, F.R.S.

I have been allowed to examine the typical specimens of *Ortonia* and *Conchicolites* which Prof. Nicholson has described in his various writings, and also the *Tentaculites minutus* of Mr. James's MS. I cannot but accept the two genera of Nicholson; but the specific characters of the American are not wholly applicable to British specimens. I am therefore compelled to describe them as new. In dealing with this group I have endeavoured to represent as fairly as possible the views of other authors; yet the very poor details furnished by them give small help in the way of original research. Nearly all the species are described superficially, and but little evidence of structure is afforded. Some of the figures in Murchison's 'Siluria' and in the 'Silurian System' are represented as having been polished, and so the peculiar characters of the walls of the tube are shown. The striation, too, of the smaller specimens of *Cornulites* can be examined, so as to obtain evidence of superficial structure; but as some of the examples * in the 'Siluria' are represented as being wholly attached to some foreign object, and as one of the characters of the genus *Cornulites* is that it is "attached by its smaller extremity to some foreign body," the species thus figured must of necessity be placed in another genus. I shall therefore arrange the described genera of Tubicolar Annelida of the Palæozoic formations as follows:—

I. Cornulites, Schlotheim, Petrefacten, 1820.

Tube annulated, striated longitudinally, attached by some portion of its extremity to foreign bodies.

II. Conchicolites, Nicholson, Geological Magazine, Feb. 1873.

Tube annulated, devoid of longitudinal striæ, slightly curved, attached by its smaller extremity to foreign bodies.

III. Ortonia, Nicholson, Geological Magazine, October 1872.

Tube annulated; cellular or not along the surface opposite to its attached portion; slightly flexuous and attached along the whole of one side to some foreign body.

IV. Spirorbis, Lamarck.

Tube spirally twisted into an orbicular form, depressed, and adhering below. The spiral may be either right-handed (*dextral*) or left-handed (*sinistral*).

V. Tentaculites, Schlotheim, Petrefacten, i. p. 377 (1820).

Tube annulated; devoid of longitudinal striæ or of cellular structure; conical, straight, tapering towards one extremity, and wholly unattached to any foreign body.

* Plate xvi. 'Siluria,' ed. 1859.

As I am not aware of the existence of any special terminology applicable to fossil Tubicolar Annelida, the following explanations of the few terms I shall use in my descriptions may be appreciated.

Tube: the whole of the shell of any one of the species.

Superior annulations: the ring-like divisions of the walls of the tube which show structure in section.

Inferior annulations: the intervening rings between the superior annulations in *Tentaculites* &c.

Lateral annulations: the prolonged annulations by means of which the tube is attached to foreign bodies.

Longitudinal striæ: markings having a structural character which cover the external surface of one genus of Tubicolar Annelida.

Intersected striæ: striæ, longitudinal or transverse, intersected by other striæ.

Subkingdom ANNULOSA.

Division BRANCHIATA.

Class II. ANNELIDA.

Order III. *TUBICOLA.*

Body protected by a calcareous or arenaceous tube. Branchiæ attached to or near the head.

Genus CORNULITES, Schloth.

In this genus the animal was solitary, inhabiting a shelly tube of carbonate of lime. The tube gradually tapering and slightly flexuous, attached by its *smaller extremity to some foreign body.* Walls of the tube very thick, composed of numerous imbricating conoidal rings, their widest edge next the slender base, subirregular in old specimens, more or less distorted or oblique in the young; external surface obscurely annulated, *finely striated longitudinally*; inner surface and casts scalariform, with two or three longitudinal furrows*. The only well-known species, *C. serpularius*, Sch.

Ref. Schloth. Petref. t. xxix. fig. 7; Sil. Syst. t. xxvi. figs. 5–8.

In the 'Cambridge Catalogue,' p. 128, Salter describes *C. serpularius*, Schl., as "a shelly tube, with cellular varices (knots) like *Tentaculites*, also grows in knots of 3, 4–8 young shells, separating afterwards."

Ref. Siluria, 2nd ed., pl. xvi. figs. 3–10.

Loc. and Formation. Typical *Cornulites*, Wenlock Limestone.

Dwarf specimens about an inch long, Upper Ludlow Rocks, Westmoreland. I cannot identify any of the species found in the Wenlock shales with either the typical *C. serpularius*, Schl., or the dwarf specimens referred to by M'Coy in his Brit. Palæozoic Fossils.

1. CORNULITES SCALARIFORMIS, n. sp. (Pl. XV. figs. 1, 9 & 10.)

? *Tentaculites scalaris* of Sil. System and Siluria.

? *Tentaculites anglicus* of authors (part of Salter's sp.).

* Brit. Pal. Fossils, p. 63; and Nicholson, "On the Genera *Cornulites*," &c., Am. Journ. Sci. 1872, vol. iii. p. 203.

Tube hollow, attached by a portion of its proximal end to foreign bodies, the greater portion free. Very many fragments frequently found in the shales, varying from about a quarter to three quarters of an inch. Annulations superior, separated by depressed intervals, which give to the fragments a kind of scalariform aspect; strongly marked with "longitudinal" striæ, the width of which varies from $\frac{1}{100}$ to $\frac{1}{124}$ of an inch; the tube is again marked with transverse intersected striæ, varying from $\frac{1}{300}$ to $\frac{1}{250}$ of an inch in width. This cross-hatching gives to the tube a very peculiar character, and in all probability represents "cellular varices" of Salter and others.

Loc. Lower Wenlock Shales, no. 40; Upper Wenlock Shales, Tickwood beds, no. 41. Rare in both beds.

Remarks. It is quite possible that *C. scalariformis* may be upon a cursory examination identified either with *Tentaculites anglicus* or the smaller specimens of *Cornulites serpularius* of authors. The anomalous characters of both of these species cause me to approach them with a great amount of diffidence; and I am not certain that I shall improve the anomaly by the doubtful synonyms I have placed under the species described above. The following are my principal reasons for removing this species from the region of doubt. The peculiar annulations and striation of *C. scalariformis* are unique. I know of no other species with which I can compare it. In Salter's *T. anglicus* the external walls of the tube are longitudinally marked, and the transverse section shows by the small opening that the real diameter of the tube corresponds with the contraction of the vertebra-like section, which professes to be an enlargement of a fragment of the more perfect specimen. Otherwise than this there is no correspondence between the two types. Again, the structure of the walls of the tube when examined in section is altogether different in *C. scalariformis* from that of any typical *Tentaculites.* Salter's species is straight and unattached (?). This is sufficient in itself to show amongst which group it should be placed if it be a true *Tentaculites*; but I have satisfactory evidence that the species described above was not free.

Since writing the above I have been furnished with examples of the species from Gotland by Professor Lindström, of Stockholm. One fragment is attached to a valve of *Meristella* (*Whitfieldia*) *tumida*, and the proximal end is covered by a coral growth; the other specimens are unattached, but are identical with our own. The following are the microscopical characters of this species:—

Tube hollow, having a somewhat uniform diameter, which corresponds with the growth of the shell, widening gradually from a diminutive point to the distal extremity. Interior filled either with clay or calcite. Walls of the tube still retaining their normal character, varying in thickness from $\frac{1}{50}$ to $\frac{1}{20}$ of an inch. Superior annulations permeated by circular, oval, or angular cavities, a character which will be seen to more advantage in the drawing. In the transverse section of the species the longitudinal striæ appear

like spines, and these are developed apparently from an outer layer of the wall of the tube. Walls partaking of a laminar structure.

I have examined a great number of recent and fossil Annelida, but I cannot find in any of the calcareous tubes special characters corresponding with those of *C. scalariformis*. It is therefore to be hoped that this crude description will direct towards the *Cornulites* of the Silurian epoch the attention of critical palæontologists both at home and abroad.

Genus CONCHICOLITES, Nicholson.[1]

Conchicolites, Am. Journ. of Science, March 1872. Type *C. gregarius*, Nich.

Conchicolites, Geol. Mag. Feb. 1873. Sp. *Conchicolites corrugatus*.*

This genus was founded by Nicholson, and referred to in full in the above papers and in his Palæontological and Natural History Manuals, for species which in all probability would be referred by authors to *Cornulites*, Schlot. The distinction between the two genera is something more than merely superficial; there are structural differences which widely separate the two groups, and in this paper I have given in my synopsis the leading and typical characters of the genera. I have not the material at hand to reexamine *Cornulites*, and I have only reproduced the textual outlines of previous authors. This is to be regretted; but I was unable to obtain specimens for a closer examination. I have, however, gone very carefully over the whole of the figures and text of both the 'Silurian System' and 'Siluria,' and also the details of Prof. M'Coy. In the separation of the present genus from *Cornulites* Prof. Nicholson has my warmest appreciation.

2. CONCHICOLITES NICHOLSONII, n. sp. (Pl. XV. fig. 2.)

Tube minute, calcareous, varying in length from 1 to 2 lines. Annulations very irregular, close or compacted together near the proximal end, rather more separated towards the distal end, the average number about ten to a line. Proximal end of the tube connected by lateral annulations to foreign objects, the remaining portion free.

Loc. Rather common in the Buildwas beds, no. 22; rare in the other washings. It is also present, but not abundant, in the Tickwood beds, nos. 25 and 42. Above these beds I have not detected it.

This beautiful and delicate Annelid I dedicate to Prof. Nicholson, on account of the very valuable labour which he has bestowed upon this genus. The species is a variable one, especially in the upper beds, but more in its manner of attachment than in the delicacy of its annulations. Beginning as a mere point, the tube assumes its normal character very early. For about $\frac{1}{30}$ of an inch the rings are very fine, and these are produced laterally, as the mode

* In this paper and description of figures the student must reverse the figures in text, &c.:—Figs. 2, 2*a*. *Ortonia minor*; figs. 3, 3*a*. *Conchicolites corrugatus*.

of attachment to foreign objects, either corals or shells. After the tube becomes fixed there is a gradual bending outwards, and sometimes for more than two thirds of its length it is free. Nearly all my specimens are separate in the shales, and I cannot therefore give any information as to whether the species was solitary or social.

3. Conchicolites gregarius, Nicholson.

Conchicolites gregarius, Nicholson, Amer. Journ. Sci. March 1872; Geol. Mag. Feb. 1873; Manual of Palæontology, &c.

Var. rugosus, n. var.

Tube calcareous, varying in length from 2 to 4 lines. Annulations irregular and rugose, sometimes entire or completely surrounding the tube, at other times forming imperfect rings only, about four in the space of a line. Diameter of the tube varying from three quarters of a line to a line; mouth about half a line. Attached by some portion of the proximal end of the tube and by lateral annulations to foreign bodies.

Loc. Rather common in small fragments in the Buildwas beds, no. 22. Finely preserved in 38 and 40. Very rare in Coalbrookdale beds, no. 43. Present but not abundant in Tickwood beds, no. 25.

There is no possibility when care is exercised of confounding the present species with the former. The abundance of the two species in the same beds (no. 22 washing) affords a good opportunity of making a comparison between them. I have some specimens of *C. Nicholsonii* nearly the same length as the *C. rugosus*, and I can find that from the beginning and throughout the whole growth of the tube the characters of the two species are clearly defined. I have, however, preferred to give this type a varietal rather than a specific name. I cannot say positively that this is a form of Nicholson's species, but there seems to me a probability of its being so. When *C. gregarius* was described, the author had to depend on either a clustered mass attached to a shell of *Orthoceras Brongniarti* or upon casts. Neither of these show any structure; but the cast figured by Nicholson * is so characteristic of *Conchicolites*, that I feel a pleasure in being able to remove any difficulty that obscures the description. Still there is a doubt, and to avoid any confusion I have fully described the variety.

There is a remarkable peculiarity about the superior annulations of *C. rugosus*. Whenever the tube is worn and the rotundity of the annulations destroyed there appears to be a number of lines only, and the space between these filled in with matrix. In normal character the rings are like an ordinary wedding-ring, round on the outside. If this rounded part be slightly rubbed small cavities appear, like pin-holes; more rubbed, these are widened into lines; deeper still, the apparently solid ring is divided into two lines, and

* Manual of Palæontology, vol. i. p. 312, fig. 182 (ed. 1879).

the matrix seen in rubbed specimens is the contents of the rounded hollow annular layers of growth of the tube. A very close correspondence therefore exists between this ancient type of Tubicolar Annelid and a similar one dredged from the Bay of Naples (50 fathoms), picked out from material sent to me by Mr. A. W. Waters, F.G.S. The recent species is not much longer than *C. Nicholsoni*, but it reveals the structure of the annular layers very satisfactorily; and one of my specimens is attached by its proximal end to a fragment of shell, but the point of attachment is covered by a small colony of *Cellepora*; the rest of the tube is free.

Genus Ortonia, Nicholson.

Ortonia, Nicholson, Geol. Mag. 1872. Type *O. conica*, Nich., Silurian.

Ortonia, Nicholson, Geol. Mag. 1873. Sp. *O. minor*, Nich., Silurian.

Ortonia, Nicholson, Geol. Mag. 1874. Sp. *O. intermedia*, Nich., Devonian.

This genus was originally founded by Prof. Nicholson for the first of the three species named above. *Ortonia conica* is of a cellular character along the plane opposite to the plane of attachment. The other species are somewhat different from the original *O. conica*; and upon the publication of the characters and figures of *O. minor* Mr. John Young, of Glasgow, published in the 'Geological Magazine,' 1874, his description of *Ortonia carbonaria* * of the Carboniferous formation of Scotland as nearly identical with *O. minor*. I can now add to our British Silurian fauna at least two types of this genus from the Wenlock Shales.

4. Ortonia conica, Nicholson.

Ortonia conica, Nicholson (type), Geol. Mag. 1872.

Var. pseudo-punctata, n. var. (Plate XV. fig. 3.)

Tube solitary, slightly flexuous, adherent to stems of Crinoids; average length about two lines. Along the plane opposite to the attached side are apparently minute punctures, corresponding to the punctured surface of the type species. Walls of tube comparatively thick; mouth or orifice small. Attached by lateral annulations. In one specimen, two lines in length, there are sixteen rings, most of which are prolonged laterally.

Loc. Buildwas beds, 22 and 38.

This variety is better preserved in no. 22 than in no. 38. It is very rare, however, in the first-named washing, but rather more abundant in the last. It has, as will be seen by the description, many of the characters of the species; the most marked differences are the size and the punctations of the surface.

* I have a fine series of this type in my cabinet, which has been a very great help to me in the study of the Silurian species.

5. Ortonia serpuliformis, n. sp. (Plate XV. fig. 4.)

Tube minute, attenuated-flexuous; adherent to species of corals; varying in length from one and half to two lines, but much more delicate in every respect than the last species. Tube adherent by its whole length; and in one specimen, in which the coral was too small, the distal part of the tube, gradually adapting itself to circumstances, turned over, and became adherent to the cross section of the coral.

Loc. Middle Wenlock Shales, Coalbrookdale beds, no. 43; Upper Wenlock Shales, Tickwood beds, no. 25.

Specimens of this species are rare, and I have not found it in any of the washings except the above, and only on corals. I cannot identify it with any of the species described by Prof. Nicholson; and as it closely resembles the attenuated proximal end of *Serpula vermicularis* of Brown's 'Conchologist's Text-Book,' pl. xix. fig. 14, I give it the above specific name. I do not know the recent species; and without having details of the species figured, I have no desire to make any comparison between the recent and the fossil type.

Genus Spirorbis, Lamarck.

6. Spirorbis arkonensis, Nicholson.

New Devonian Fossils, Geol. Mag. 1874.

Tube minute, dextral, of two turns, the last turned upwards. Aperture circular. The diameter of the entire spiral is about one third of a line. Surface sparingly marked with annulations.

Loc. Buildwas beds, no. 22; Tickwood beds, no. 25. In this bed there is only a section of the tube preserved.

I have adopted Nicholson's name *S. arkonensis* for this most delicate Annelid. In my description I have accepted in part the diagnosis of the American Devonian fossil. There is a slight difference in the two forms, but so slight indeed that, unless one wanted to be very scrupulously exact, the two may pass unnoticed under one name. In measurement, but not in ornamentation, the two species are as nearly as can be the same.

Species belonging to this genus are exceedingly rare in the shale-washings. Only two out of the eleven localities have as yet yielded me specimens. One specimen from no. 22 is tolerably perfect and on a fragment of shell; the other is a section (base) of the tube on the tube of *Conchicolites Nicholsoni*. The specimen from no. 25 is on a fragment of coral; and this, too, is only a section.

The record of *Spirorbis* as a Silurian fossil is very meagre. No evidence is afforded by the collection in the School of Mines that it existed prior to the period of the Wenlock Shales. As the shales are derived from rocks of a previous age, its true home is not yet found. Very little additional detail is given in Mr. Robert Etheridge's famous address to the Geological Society. For specific details Sowerby's, so far as I am aware, is the only British species described. The following are the recorded Silurian species:—

Lower Wenlock Shales.

Buildwas beds, 22	*Spirorbis arkonensis*, Nich.
Coldwell Flags, Westmoreland	*Spirorbis*, sp., Wyatt-Edgell.

Upper Wenlock Shales.

Tickwood beds, 25	*Spirorbis arkonensis*, Nich.

Wenlock Limestone.

School of Mines Cat. p. 101	*Spirorbis Lewisii*, Sow.

Upper Ludlow.

School of Mines Cat. p. 117	*Spirorbis*, n. sp., Murch.

Bone-bed.

School of Mines Cat. p. 129	*Spirorbis Lewisii*.

An important addition to my cabinet is a slide containing two or more species of *Spirorbis* and several specimens, given to me by Mr. Smith, and procured by him from the washing of shales from Lincoln-Hill Iron Bridge. It is beside my purpose to enter into details respecting these, because they do not belong to the shale-washings of Mr. Maw. I allude to their existence to prevent any misconception that may arise in the mind of the student when reading my remarks on the paucity of *Spirorbes* in the shale-washings.

Genus Tentaculites, Schlotheim.

Tentaculites, Restricted by Nicholson, American Journ. of Science, 1872, p. 204.

The genus *Tentaculites*, like many other Palæozoic genera, has had a very chequered palæontological history. By its author certain forms were regarded as the tentacular appendages of some of the Crinoids. Species figured in the 'Silurian System' were placed amongst the "incertæ sedis." In M'Coy's 'British Palæozoic Fossils' they were similarly placed; but one of the authors says, "I can see no reason for believing these bodies to be portions of Crinoids, as suggested by many authors, much less spines of *Leptæna*, as suggested by others; their small size, general form, and the appearance which large clusters of them often present on the surface of the beds, gives one the idea of their belonging to the Pteropoda. . . . . Their being unattached, small size, and straight, regular form, separate them from the allied genus *Cornulites*"*. The same view of the zoological position of *Tentaculites* is taken by Prof. Nicholson in his various writings. Salter, however, believed these, as well as the species of *Cornulites*, to belong to the Tubicolar Annelida; and Mr. Robert Etheridge†, seems to take a similar view in his address to the Geological Society.

Not knowing the special structure of the shell of the Pteropoda, to which the Palæozoic species may possibly be allied, I cannot

* Brit. Pal. Fossils, p. 63. † Presidential Address, 1881.

institute the comparison that I should wish. If it be placed with *Theca* of Morris, a synonym of which is the *Creseis* of Forbes, then the nearest approach to the type is the Atlantic species *C. aciculata*, Rang; but in this type, as figured in Woodward's 'Manual of the Mollusca' (pl. 14. fig. 34), there is no appearance of annulations, and this is one of the chief peculiarities of *Tentaculites*.

The material for a complete study of this group, irrespective of its zoological affinities, is afforded by specimens in the shales. I do not think I am justified in placing upon record more than four species as prevalent in the washings; but their remains are so abundant, and so well preserved, that sections of the shells afford reliable evidence as to their special structure; and I must be pardoned if I step a little beyond the purely geological for the purpose of showing the microscopical evidence which the sections reveal. When the facts are formulated, a comparison can be made between the shells of *Tentaculites* and recent Pteropoda. I have been deceived so often in the mere external features of Palæozoic fossils when making a comparison with recent apparently allied types, that I feel certain a check upon hasty conclusions will be of the same value in researches of this kind to others as to me. There are other investigations outside of the pale of palæontological inquiries which must act as factors in the lines of research, as well as mere morphological details, and these must come in to help in the decision as to the zoological affinities of fossil types. I refer now especially to the masterly address of Dr. Sorby to the Geological Society in 1879.

In this address Dr. Sorby refers to the mineral constituents of certain shells, and he says that "this difference in the state of preservation of fossils, according as they were originally composed of calcite or of aragonite, appears to be so well established in all those cases in which we are able to ascertain the true mineral nature of closely allied living organisms, that I feel myself justified in concluding that certain doubtful fossil forms were originally calcite, because they are preserved like those in the same thin section known to have been so; whilst those known to have been aragonite have become quite crystalline and lost their original structure" *. Of Annelida Tubicola he says, "probably calcite, but they include many foreign fragments" †. Further on, again, he says "The shell has usually a more or less distinct laminar structure parallel to the surface of growth. The calcite is in the form of minute granules, often without any definite optical orientation" ‡. As the *Tentaculites*, which will be referred to again, do retain their original structure, we may reasonably suppose that the shell at least was composed of calcite. I hope that these special mineralogical details will assist in guiding our judgment as to the proper zoological position of these unique Silurian fossils, as well as the more special and morphological details of authors.

* Dr. Sorby's Anniversary Address, Q. J. G. S. 1879, vol. xxxv. p. 68.

† Ibid. p. 60. ‡ Ibid. p. 63.

According to Prof. Nicholson, "The restricted genus *Tentaculites* may be defined as including small shells which have the form of STRAIGHT conical tubes, tapering towards one extremity to a pointed closed apex, and expanding towards the other to a rounded aperture. The shell is FREE; and its walls are thin, and are surrounded by numerous thickened rings or annulations." I have no evidence for the latter clause of Prof. Nicholson's restricted types; and I cannot therefore adopt it in this paper. His words are these:—"*sometimes with intermediate striæ over the whole or part of the length of the tube*" *.

This part of the above is for the purpose of including the peculiar species of Salter; and to prevent any misconception, I reproduce the bibliography of this remarkable type.

7. TENTACULITES ANGLICUS, Salter, Siluria, 2nd ed. pl. i. fig. 3.

Straight, unattached, worm-tubes, resembling some horny Mediterranean species; and still more like the *Cornulites serpularius* of the Wenlock and Dudley Rocks (Cambr. Cat. p. 47).

T. scalaris, Schl., Sil. Syst. pl. xix. fig. 15.

T. scalaris, Schl. Llandovery species, internal cast of *T. anglicus* (Salter, Siluria, p. 221).

T. annulatus, Schl., Sil. pl. x. figs. 2 and 3 (ed. 1859).

T. anglicus, Salter (Siluria, 3rd ed. pl. i. fig. 3); *T. annulatus*, Sil. Syst. The *T. annulatus* is a Devonian form without the fine longitudinal striæ (Salter, Cambr. Catalogue, p. 76).

T. annulatus, Salter, fig. 547; Lyell, Elem. of Geology, ed. 1871 (fig. 553, ed. 1878).

"Of the sixteen species of Annelida only two pass to the Lower and Upper Llandovery, *T. anglicus* and *Cornulites serpularius*. They range also to the Ludlow."—(Mr. Etheridge's Presid. Address, p. 108.)

I cannot identify the species in any of the Wenlock-Shale washings. If Salter's figures are to be relied upon, the nearest approach to the type is *Cornulites scalariformis* (see *ante*, pp. 379, 380); but this species is attached, and not free, as *T. anglicus* is said to be.

8. TENTACULITES ORNATUS, Sowerby.

Type, 'Siluria,' fig. 11, plate xvi., especially the section magnified.

? *T. annulatus*, His. Lethæa Suecica, pl. xxxv. fig. 2 (1837).

Tube delicate, elongated, free, varying in length, but of unknown dimensions as regards the fragmentary condition of specimens found in the shales. Superior annulations placed at varying distances, about three to a line, spaces between marked by inferior annulations. Walls of tube thin, the hollow interior about two thirds the diameter of the tube, which, towards the distal extremity, is about half a line. The annulations at the proximal part of the tube, for about a line and a half from base, about 5 to a line.

Loc. Coalbrookedale beds, no. 43, rare; Tickwood beds, no. 25,

* Geological Mag. Oct. 1872. *Italics* mine.

also rare. Shales over the Wenlock Limestone, no. 46, rather more frequent.

In accepting this species as a Wenlock-shale type, I rely entirely upon the authority of fig. 11, pl. xvi. of 'Siluria,' 1859. In these figures we have a magnified portion given as a section. There are three superior annulations; and the lateral spine-like prolongations would reveal the typical structural characters of the genus if examined by the microscope, which will be referred to further on. A careful examination of another figure will show the intervening inferior annulations. In E. Emmons's 'Manual of Geology,' 2nd ed. New York, 1860, p. 113, fig. 102, a specimen of *T. ornatus* is figured, eight lines in length, and the diameter of the tube and number of annulations to the line are about the same as our own. This is from the Waterlime series, over the Niagara group; and it forms one of the series of the Helderberg, or upper division of the Silurian System. If Emmons's fossil is drawn from an American specimen, and the measurements can be relied upon, there is again a close correspondence between the two faunas, the British and American; for the figure is as like our own as it can possibly be. It is this type only that I accept as *T. ornatus*; my specimen of the Dudley-Limestone *Tentaculites*, named *T. ornatus* by collectors, is very different from this. *T. annulatus* of Hisinger's 'Lethæa Suecica,' from the Silurian Sandstone of Gotland, is also like some of the fragments.

9. Tentaculites tenuis ?, Sowerby.

Type, fig. 12, pl. xvi. Siluria, ed. 1859.

A reference to the above figure will show that the annulations of this species are closer together than in the above; and in the text the author of 'Siluria' says, "*T. ornatus* abounds in the Dudley Limestone, whilst a small species, *T. tenuis*, occurs in the Upper Ludlow" *. I cannot verify the identifications of those authors who refer the delicate species found in the shales to this type; and I have no specimens of the Ludlow type to compare with my own. Seeing, therefore, that the specimens to be described below are found only in the shales *over* the Wenlock Limestone, I think it best to retain the species, and describe my own as a variety:—

Var. attenuatus.

Tube very delicate and attenuated, of variable length, but specimens found in the shale-washings are from about one and a half to two lines long. Annulations superior, about twelve in the space of a line. Average diameter of the tube near the proximal end $\frac{1}{60}$, near the distal end $\frac{1}{48}$ of an inch. Walls of the tube thin, aperture round, and the length of the last or newest chamber nearly occupying the same space as three ordinary annulations.

Loc. Shales *over* the Wenlock Limestone, no. 46.

If this be *T. tenuis*, or a variety of the same, I shall be glad to fix

* Ed. 1859, p. 259.

the true type as above, for very special reasons. *Below* the Wenlock Limestone there are other *Tentaculitæ* equally delicate, but having characters in the annulations altogether different from the above; and unless these be separated, it is quite possible that collectors, at least, will confound the two types. This, to me, is of little importance; I seek to separate them on account of their significance in the palæontology of the shales.

10. Tentaculites wenlockianus, n. sp. (Pl. XV. figs. 5, 6 & 11–13).

Tube delicate, elongated, varying in length from one to two and a half lines. Superior annulations in two series. The first series composed of rings alternately tumid and depressed, separated from each other by intervals of about a half of a line; the second series occupying the intervals between the first, and very rarely indenting the margins of the tube to any appreciable extent. The normal number is three, occasionally two, but rarely four. Very delicate inferior annulations fill in the remaining space; and these sometimes cover the superior annulations transversely. Average diameter of the tube near the proximal end about $\frac{1}{50}$, towards the distal end from $\frac{1}{20}$ to $\frac{1}{16}$ of an inch. Walls varying in thickness according to the tumid or depressed character of the tube; aperture circular.

Loc. The figures are given from specimens found in the lowest Buildwas beds, nos. 22, 36, & 38; Coalbrooke Dale beds, no. 43; Tickwood beds, no. 25. Shales above Wenlock Limestone, no. 46.

This species is found in fragments in most of the washings of the shales; and its range is from the lowest bed of the Buildwas series to the shales over the Wenlock Limestone. A reference to the figures will show the peculiarity of the annulations of both series; and this character is so constant that it matters not how small the fragment is, provided it is large enough to show at least two. The first series of rings gradually swell out to, and as gradually recede from, a central line. I have some fragments not more than $\frac{1}{50}$ of an inch in diameter; and the character is as constant in these as in those of $\frac{1}{20}$ or $\frac{1}{16}$ of an inch in diameter. This is a true Wenlock-shale type; and I think it may appropriately be named as above. There is, however, another type that has a range equally significant; but its characters are altogether different.

11. Tentaculites multiannulatus, n. sp. (Pl. XV. fig. 7.)

Tube small, varying in length from a half to two and a half lines. Superior annulations closely compacted together, without the ordinary interspaces or inferior annulations seen in other species; average number about 20 in the space of a line. Walls very thin; aperture circular. Diameter of tube $\frac{1}{30}$ to $\frac{1}{16}$ of inch.

Loc. Buildwas Beds, no. 22; Tickwood beds, 25. Shales over the Wenlock Limestone, no. 46.

I was for a very long time very diffident about placing this species with *Tentaculites*. My reasons for doing so now are these:—1. The tube is always found *free*, never attached; 2. The superior annulations,

though compacted together, are of the same character, structurally, as in other true *Tentaculitæ*; 3. The tube, though always filled either with calcite or clay, was evidently, in its natural state, hollow. My doubts are on account of the following facts elicited by a comparative study of the numerous specimens:—1. There are none of these Silurian specimens that can in any way be confounded with *Conchicolites* as limited in this paper; but to some extent the exterior annulations are very much like those of some specimens of that genus; structurally they are different. 2. Some of the Carboniferous *Ortoniæ* that are found free in the shales are also like the Silurian specimens described above as *Tentaculites*. 3. The one fact obtained by the study of specimens found in the shales *over* the Wenlock Limestone which compels me to place my doubt upon record is this: from these shales I have one fragment of *T. ornatus*, one line in length, half of which is true *T. ornatus*, the other half apparently *T. multiannulatus*. I cannot explain the fact; but I feel that it is incumbent on me to place it upon record.

Genus Psammosiphon *, gen. nov.

After completing my paper, as above, on the Annelida Tubicola, I was obliged to lay aside a mass of materials, chiefly from the Tickwood beds, on account of their many peculiarities. Amongst these were a group of Annelid remains that I was unable to refer to any existing genus, either recent or fossil. They were of an arenaceous texture, with very decided characters, both external and internal; and I was in doubt whether they should be referred to the Protozoa or placed with the Annelida. Since then I have examined an immense number of specimens, and I feel convinced that they may find a fitting resting-place with the latter group. Since, however, there is no genus known to me under which the species could be placed, I have been compelled to found a new one for their reception.

Generic Characters. Body irregularly disposed, crowded or tubular, composed of minute grains of sand; adherent to shells, stones, or corals, or free, but flattened at the base, showing evidence in the free specimens of former attachment.

The genus *Serpula* has a protecting tube composed of carbonate of lime; but the *Sabellariæ* and *Terebellæ* have, generally speaking, arenaceous tubes; these genera, however, are of too decided a character to admit without violence the Palæozoic species. Every other genus referred to by Prof. Nicholson and Mr. Robert Etheridge, Jun., in their joint work 'On the Silurian Fossils of the Girvan District of Ayrshire' †, and by Prof. Nicholson in his 'Palæontology,' are likewise unsuitable for the admission of the species enumerated below.

12. Psammosiphon elongatus, sp nov.

Tube elongate, serial or biserial, varying in length from $\frac{4}{20}$ to $\frac{5}{20}$

* This name is substituted for *Arenatubulites*. † Fasciculus iii. pp. 303–318.

of an inch, and with a transverse diameter of about $\frac{1}{20}$ of an inch. Composed of grains of shelly sand, with here and there minute grains somewhat larger than ordinary; slightly tapering towards the base. Orifice circular, with a rounded lip, thinning outwardly, and of rather larger dimensions than the normal size of the tube.

Loc. Tickwood beds, no. 25, rare. I am rather doubtful of species found in the Buildwas beds. Type specimen from no. 43, Coalbrookdale beds.

13. Psammosiphon amplexus, sp. nov. (Plate XV. fig. 8.)

Tubes irregularly clustered, embracing, forming sandy mounds, varying in size from one eighth to a quarter of an inch and more in breadth and height. Orifice circular, at the apex of small papillæ, which, in the most perfect state, stand out from the general mass of surrounding material, forming the distal part of the otherwise enclosed tube. Adherent by a flattened base to shells, stones, and, rarely, corals.

Loc. Tickwood beds, abundant in no. 42, less abundant in nos. 25 and 41.

Unlike the first species, which is to some extent solitary, this species is remarkable for its sociability. Beginning as a small, scarcely definable tube upon a fragment of stone or shell, it is soon followed by others, till a series are clustered together, so as to form groups of unknown dimensions. In the shale-washings the specimens are more frequently found free than attached. On the flattened or previously adherent side the exposed tubes are seen, varying in length from $\frac{1}{20}$ to $\frac{1}{50}$ of an inch.

The clayey sand, out of which the Annelid builds its tube, is of a pale yellow colour; and it is very rare to find specimens of a different tint. If broken up and examined under the microscope, it will be found that this sand is formed out of the débris of shells more frequently than out of other débris; and the whole is cemented together apparently by a chitinous secretion from the body. I cannot detect any particular structure in the tiny tubes; internally they are smooth and round and have a diameter rather less than the orifice of the tube when seen externally.

With our present incomplete knowledge of these fossil organic remains, I do not think I should be justified in an endeavour to establish more species of *Psammosiphon* than the two of which details are given above. Independently of my own labours, and entirely unknown to me until I saw the slides containing the specimens for naming, Mr. John Young, of the Hunterian Museum, Glasgow, discovered *P. amplexus* also in his Wenlock Shales *. I have also had, for examination and naming, the slides of Mr. J. Smith, of Kilwinning, procured from washings from the shale-heaps and railway-cuttings round Benthal Edge and Coalbrookdale †. Amongst these slides there were specimens of *Psammosiphon elongatus*

* From the Tickwood beds.

† A list of Entomostraca from these washings was given by Prof. Rupert Jones in Geol. Mag., Feb. 1881.

and *amplexus* from the railway-cutting opposite Swan Iron Bridge. Mr. Smith also procured specimens of *Tentaculites*, *Conchicolites* and *Cornulites* described in this paper.

There is, however, additional interest in the discovery of the arenaceous Annelid of the Silurian Shales. When sending his slide to me, Mr. John Young said :—" An almost identical form is found in the washings of the Hairmyres Shales from the Carboniferous formation of Scotland. At Hairmyres I have found it in somewhat larger fragments, and adherent to the stems of Crinoids and fronds of *Fenestella*—which shows that this Annelid was not a free form, but attached itself to other bodies. . . . . The Carboniferous species I have not yet met with in any other locality than the one given "*.

This completes my list of Tubicolar Annelida found in the shale-washings. Throughout the whole of the series I have not found any specimens which may undoubtedly be placed with the Annelida Polychæta of Dr. G. Jennings Hinde. I have found one specimen of a small jaw very much like the outline of the Much-Wenlock *Œnonites aspersus* of that author. It is serrated like that species, only with a less number of teeth; but the hook-like termination is also serrated with three teeth, and under the teeth of the longest part of the jaw there are circular places. The specimen is about a line and a half in length. It is from the shales over the Wenlock Limestone, no. 46.

In the figures of sections I have endeavoured more particularly to show the structural character of the tubes in the types of *Cornulites* and *Tentaculites*. These are so different that they must strike the eye at once; but my main object is to form a basis of future comparison for the more detailed study of the leading types of the Tubicolar Annelida.

EXPLANATION OF PLATE XV.

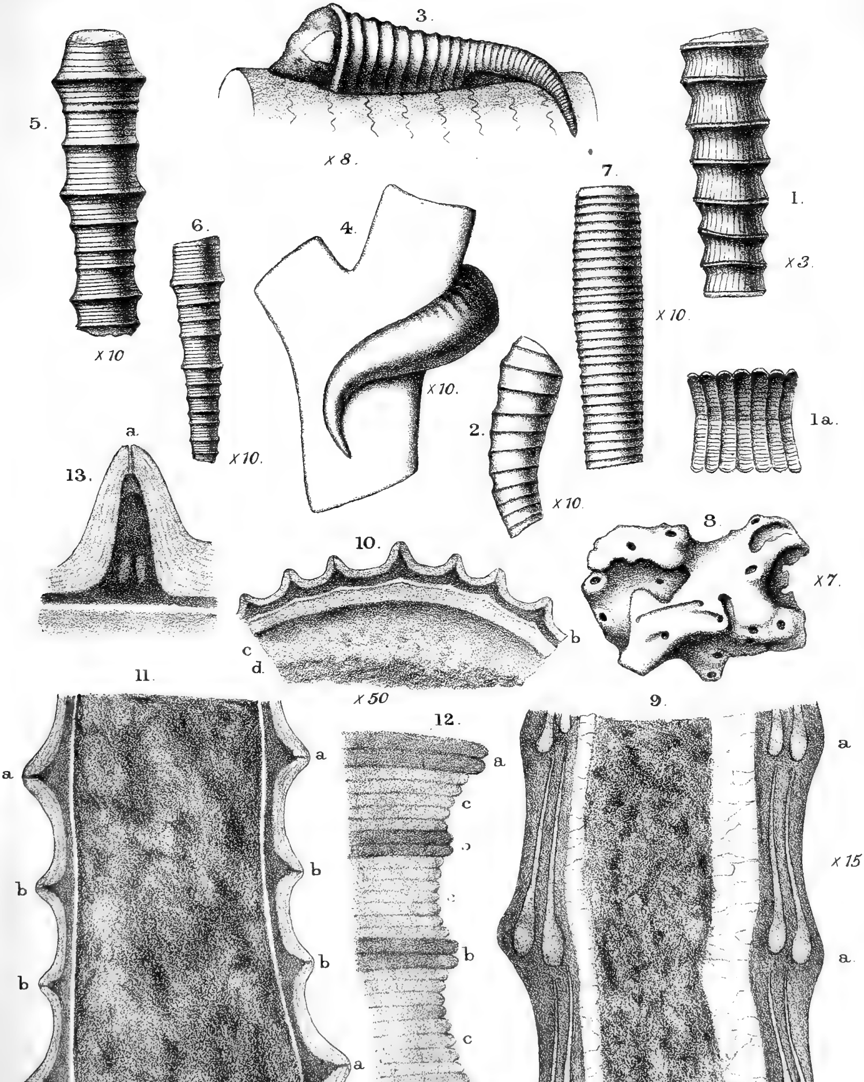
Fig. 1. *Cornulites scalariformis*, Vine, × 3. 1 *a*. Portion of surface with longitudinal striæ, further enlarged.

2. *Conchicolites Nicholsoni*, Vine, × 10.
3. *Ortonia conica*, Nich., var. *pseudopunctata*, Vine, × 8.
4. —— *serpuliformis*, Vine, × 10.

5, 6. *Tentaculites wenlockianus*, Vine, × 10.

7. —— *multiannulatus*, Vine, × 10.
8. *Psammosiphon amplexus*, Vine, × 7.
9. *Cornulites scalariformis*, Vine; longitudinal section of tube, showing:—*a*, *a*, *a*, three of the superior annulations; *b*, *b*, walls of tube; *c*, *c*, calcite; *d*, matrix. × 15.
10. —— ——, cross section of tube, × 50. Letters as in preceding figure.
11. *Tentaculites wenlockianus*, Vine; longitudinal section of tube, reversed. *a*, *a*, *a*, superior annulations; *b*, *b*, *b*, secondary superior annulations; *c*, *c*, walls of tube; *d*, matrix. × 50.

* Mr. J. Young, F.G.S. Letter dated Feb. 1882.



C. Berjeau del. et lith.

Mintern Bros. imp.

SILURIAN ANNELIDA

Fig. 12. *Tentaculites wenlockianus*; a nearly transparent section, showing the peculiar structure of the superior annulations seen in all true *Tentaculitæ*. *a*, *b*, *c*, as in fig. 11.

13. One of the superior annulations, × 110.

Discussion.

Dr. Hinde said he had seen the specimens, which were minute and fragmentary, but yet exhibited microscopic characters which might be relied on for specific description. He was not quite satisfied that some of the specimens placed in the genus *Psammosiphon* were really palæozoic. The specimen placed with a query under the genus *Œnonites* appeared to be merely a fragment of a polyzoan, and not the jaw of an Annelid. He agreed with the author in placing *Tentaculites* among the Annelids; its close resemblance to *Conchicolites* and *Ortonia* showed its affinities to be with the Worms rather than with the pelagic Mollusca, notwithstanding that it was a *free* form.

40. Description *of Part of the* Femur *of* Nototherium Mitchelli. By Prof. Owen, C.B., F.R.S., F.G.S., &c. (Read June 7, 1882.)

[Plate XVI.]

In my work on the Extinct Mammals of Australia * the osteology of the existing species is described and figured in the degree requisite for the comparisons with the fossil bones.

In the Kangaroos the femur, amongst other characteristics, shows "the rough depression (plate lxxiii. figs. 2, 3, *y*, op. cit.) above the outer condyle (ib *v*)' and "the great transverse extent of the articular surface of that condyle by the production of its outer part, changing, there, the convexity into a concavity transversely (ib. fig. 2, *w*)" †. With these may be noted the narrowness and depth of the postcondylar or popliteal fossa (fig. 2, *u*).

The corresponding part of the femur in the Wombats (ib. pl. ciii. figs. 1–4) differs in the absence of "the rough depression, *y*;" in the relatively less transverse extent of the articular surface of the outer condyle, especially at its back part; in the continuous transverse convexity of that part of the condyle, and in the minor relative depth and greater relative width of the postcondylar fossa.

In the comparison of the fossil femur of the *Diprotodon* (op. cit. pp. 231–234) the rough longitudinal depression above the outer condyle (pl. xxxiv. fig. 1, *o*) ‡, the concavo-convex hinder part of the articular surface of the outer condyle (ib. *v*), the length, depth, and relative narrowness of the postcondylar fossa (ib. *u*), with other characters of the bone, showed its closer resemblance to the femnr of the Kangaroo than to that of the Wombat or other of the larger existing kinds of Marsupialia.

In the lower or distal portion (probably one half) of a large fossil femur (Pl. XVI.) transmitted from Australia by my friend Dr. George Bennett, F.L.S., the following differences present themselves:—There is no depression above the outer condyle; but there is a rough longitudinal rising (ib. fig. 1, *o*) in the corresponding place, for the attachment of the same or homologous muscle. The hind surface of the outer condyle (ib. fig. 4) is transversely convex: in *Diprotodon* the transversely concave tract of that condyle is relatively greater than in the largest existing Kangaroo; but I may remark that in some of the still larger extinct Macropodidæ that concavity comes nearer in relative extent to the proportions shown in *Diprotodon* §. The same remark applies to the proportional breadth of the postcondylar fossa, which, though small in *Macropus rufus*, is still less in *Macropus titan*, where it repeats the character of this part in *Diprotodon*.

* 4to, 1877. † Ib. p. 390. ‡ Ib. p. 231.
§ Op. cit. pl. xxxiv. fig. 1, *v*.

In the fossil femur under description the relative breadth of the postcondylar fossa (ib. fig. 4, *u*) resembles that in *Phascolomys* *; the more equal prominence of the lateral boundaries of the rotular surface is also a character in which the fossil resembles the Wombat more than it does the Kangaroo or the *Diprotodon*, in which the greater prominence of the inner boundary is extreme †, and the antero-posterior extent of the inner condyle, including that boundary, is relatively much greater than in the present fossil.

This femur, however, presents the following differences from that of the Wombats. The rotular surface (ib. fig. 3, *q*) is relatively narrower ‡, and the outer boundary (ib. ib. *r*) is sharper; the popliteal depression, above the intercondylar fossa, *u*, which is deep and extensive in *Phascolomys*, is hardly, if at all, defined in the fossil. Moreover the size of this fossil is greater than that of the femur in the largest known extinct Wombat, in the degree in which the mandible and teeth of *Nototherium Mitchelli* § surpass those of *Phascolomys gigas* ||.

Upon the foregoing comparisons I therefore formed the conclusion that the distal portion of femur here described belongs to a species of *Nototherium*, as large, if it be not the same, as *Nototherium Mitchelli*.

The following are its dimensions, with which I add, for comparison, those of the corresponding part of the femur of a mature *Diprotodon australis*:—

	Nototherium.		*Diprotodon.*	
	in.	lin.	in.	lin.
Length	8	6	13	6
Breadth across condyles	5	9	7	6
,, , transverse, of broken end of shaft	3	1	4	5
,, , antero-posterior, of ditto	2	3	2	8
Circumference of ditto	8	4	12	0
,, above the condyles	12	2	15	3
Breadth of rotular joint	2	3	2	4
,, of intercondylar fossa	1	5	1	7

The present portion of femur is of a mature and seemingly aged individual.

The fractured surface of the femoral shaft (Pl. XVI. fig. 2) exposes the lower end of the medullary cavity, with the compact wall from 4 to 6 lines in thickness, and part of the spongy portion of the wall, the extent of which is indeterminate through abrasion. No femur referrible to the genus *Nototherium* has previously come under my ken.

This fossil is from a locality in Darling Downs, Queensland, Australia. At the time of "going to press" with the work on

* Ib. pl. ciii. fig. 2.
† Ib. pl. xxxiii., *s*.
‡ Compare with fig. 4, pl. ciii., op. cit.
§ Op. cit. pl. xlv.
|| Ib. pl. lxv.

Australian fossils no recognizable parts of the skeleton of the hind limbs of *Nototherium* had reached me.

The characters of the present specimen, like the proportions of the skull of *Nototherium* *, show a resemblance to the Wombats which at least tends to lessen the difference between the existing forms of *Phascolomys* and *Macropus*.

EXPLANATION OF PLATE XVI.

NOTOTHERIUM MITCHELLI, Owen.

(All the figures one half the natural size, and drawn without reversing.)

Fig. 1. Outer side view of the distal portion of the right femur.
2. Fractured end of the shaft of the same.
3. Front view of the distal end of the same.
4. Back view of the same.

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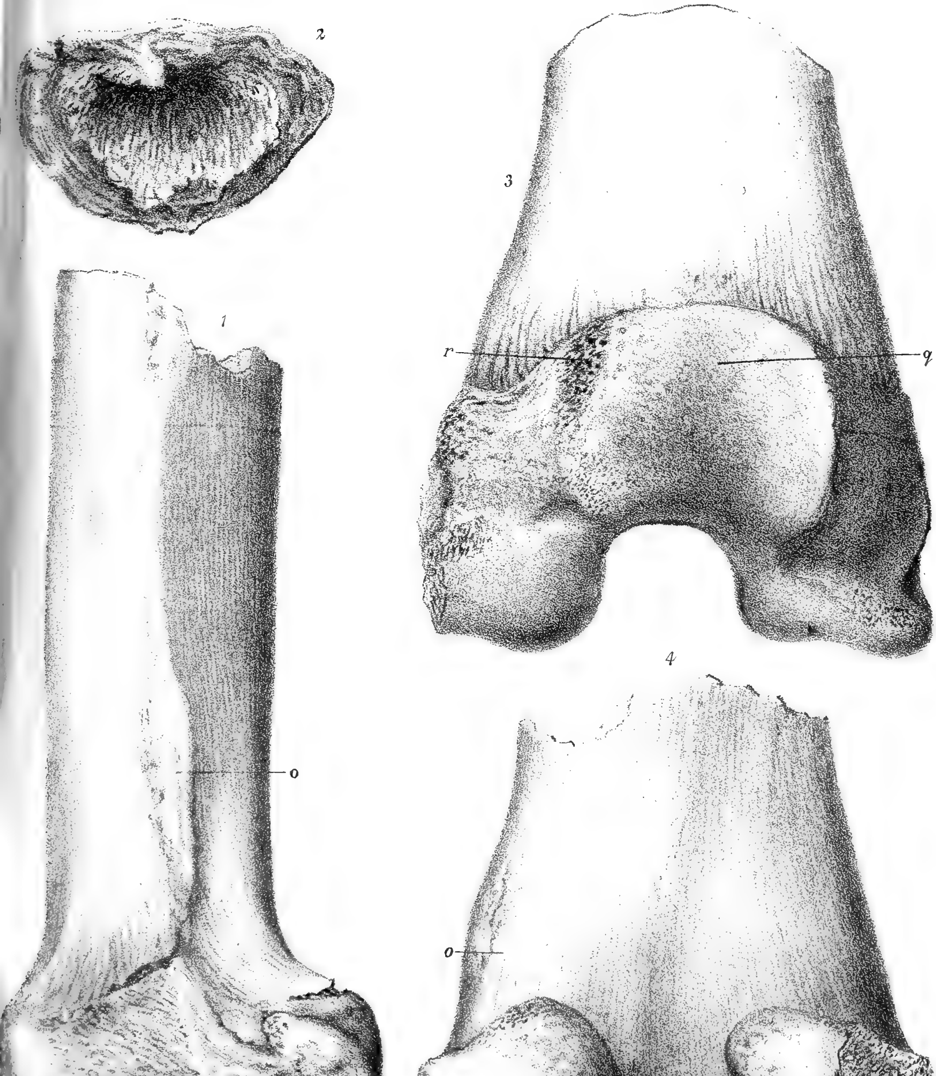
* Ib. pls. xxxvi., xxxvii.



Mary Suft lith.

Hanhart imp

NOTOTHERIUM MITCHELLI.

41. Geological Age *of the* Taconic System.

By Prof. James D. Dana, F.M.G.S. (Read April 5, 1882.)

[Plate XVII.]

A paragraph in the 'Proceedings of the Geological Society' for the 16th of November last, making part of an abstract of an address by Dr. T. Sterry Hunt sustaining the pre-Cambrian age of the Taconic schists, throws more doubt than is right on the stratigraphical observations that have been made in the region by different geologists. It does not present, as a reason for doubt, any facts from the author's personal investigation convicting these geologists of errors in their statements or conclusions, but simply mentions what the author regards as a possible source of error in any study of folded metamorphic strata, and urges this as a probable source in the present case.

The paragraph says :—"The speaker insisted upon the fact that where newer strata are in unconformable contact with older ones, the effect of lateral movements of compression, involving the two series, is generally to cause the newer and more yielding strata to dip towards, and even beneath the edges of the older rock, a result due to folds, often with inversion, sometimes passing into faults. This phenomenon throws much light on the supposed recency of many crystalline schists."

The supposed recency of the Taconic schists, and the observations which have led to the inference that these schists *overlie* certain Lower Silurian strata, are among the points to which the paragraph is meant especially to apply. It implies that in any overlying, apparent or actual, it is *an overlying of newer strata, unconformably.*

The Taconic system, first propounded by Prof. E. Emmons about forty years since, in his New-York Geological Report, published in 1842*, has found a place, right or wrong, in European as well as American geological science. Whether right or wrong is therefore a question of the highest importance. I have hence thought that a brief review of the facts bearing on the two points of *conformability to the associated rocks* and *geological age* by one of the workers in the field would be acceptable to the Geological Society.

The true original Taconic schists are those of the Taconic mountain-range, at the base of one portion of which Prof. Emmons for many years lived and laboured. The range stands along the boundary region between the States of Massachusetts and New York, extends thence northward through Western Vermont to its centre, and southward across north-western Connecticut into and through Dutchess County, New York. The general course of the

* Geology of New York: part ii., comprising the survey of the Second Geological District; by Ebenezer Emmons, M.D., Prof. Nat. Hist. in Williams College, Williamstown, Berkshire Co., Mass. 438 pp. 4to, with 17 plates, Albany, N. York, 1842.

range is nearly north and south (about N. 10° E., and S. 10° W.), and the length about 150 miles. The schists make the centre of the belt. Against nearly all the eastern side of these schists there lies a stratum of crystalline limestone called the *Stockbridge Limestone* by Prof. Emmons; and against the greater part of the western, another range of limestone, less perfectly crystalline, the *Sparry Limestone* of Prof. Emmons. These three ranges of rocks (the central of schists, the two outer of limestone) are all that need be considered: for the question is only this—are these strata conformable, or, as the cited paragraph implies, is the eastern of these limestones a newer rock than the Taconic schists, and unconformable to it?

It is plain, from these statements as to the position of the range, that the opportunities for ascertaining the relation in stratification of the Taconic schists and the adjoining limestones are not confined to a single disturbed area. They occur all along the 150 miles; and observations have been made from the northern end of the range to the southern.

The Taconic range or belt here referred to does not include all the slates of Western New England and Eastern New York to which the term was applied by Professor Emmons. But it does include those slates upon which the system was founded. He says, on page 136 of his New-York Geological Report, already referred to as his earliest publication on the subject:—

"The Taconic system, as its name is intended to indicate, lies along both sides of the Taconic range of mountains, whose direction is nearly north and south, or for a great distance parallel with the boundary line between the States of New York, Connecticut, Massachusetts, and Vermont. The counties [of New York State] through which the Taconic rocks pass are Westchester, Columbia, Rensselaer, and Washington [or those directly west of the New England boundary]; and after passing out of the State, they are found stretching through the whole length of Vermont, and into Canada as far north as Quebec. It is, however, in Massachusetts, in the county of Berkshire [the western county of the State] that we find the most satisfactory exhibition of these rocks." I may add to this statement of his that it was in the north-western part of the State, about Williamstown (long Prof. Emmons's place of residence), where stands its highest summit, Graylock, 3505 feet above tide-level, that his investigations were commenced.

We have no occasion, therefore, for taking into consideration here the Taconic slates or schists and associated strata of Northern Vermont and Canada, which are the subject of papers by Mr. Jules Marcou; or the "black slate" of the vicinity of Bald Mountain, N. Y., which was proved by its fossils to be primordial; or the so-called Taconics of other States or countries.

The stratigraphical structure of the Taconic range and its associated rocks is so simple that *all observers who have studied it have described the schists and limestones as conformable.*

In 1841, Professors W. B. and H. D. Rogers announced before the American Philosophical Society at Philadelphia, as the result of

an examination across from Stockbridge in Berkshire county, Massachusetts, on the east, toward the Hudson River on the west, that the beds have throughout an eastward dip, and make one conformable series *.

In the same year the report of Prof. Edward Hitchcock, on the Geology of Massachusetts, was published in two volumes quarto †. He states that in Berkshire or Western Massachusetts, the limestone and all the other associated rocks ("gneiss, mica-slate, talcose slate [strictly, hydromica-schist], and quartz-rock") dip, as a general fact, eastward; that these rocks are often found interstratified with one another; that, on the west side of the Taconic range, the western limestone is seen at a locality he mentions passing under the slate; that at other points west of Massachusetts the limestone alternates with argillaceous slate; and concludes "that the limestone of Berkshire County is of the same age as the rocks with which it is interstratified."

Professor W. W. Mather, one of the geologists associated with Prof. Emmons in the Geological Survey of the State of New York, and whose Report, published in 1843, makes a quarto volume of 650 pages ‡, gives, on plates 14, 16, 17, 18, sections of the rocks through the Taconic range, and to its centre (the position of the New York State boundary line); and in each of them the schist and limestone are made conformable. In the text of the Report, a chapter is devoted to the "Taconic System" (so named previously by Prof. Emmons), and the rocks are made Lower Silurian.

Professor Emmons, in the account of the Taconic system in his New-York Geological Report of 1842 (and also in his later publications on the subject §) represents the schists and limestones as conformable, and as having a prevailing eastward dip. These formations were the chief parts of his Taconic system; and this conformability was with him evidence that they were one in system. It is true he called the rocks pre-Silurian; but this was the same for all, the limestones as well as the schists.

Sir William Logan, the late able director of the Geological Survey of Canada, and one of the most cautious geologists of his time,

* American Journal of Science, vol. xlvii. p. 151, 1844.

† Final Report on the Geology of Massachusetts. 2 vols., 300 and 830 pp., 4to, with 14 and 55 plates, 1841.

‡ Geology of New York: part i., comprising the Geology of the First Geological District; by Prof. W. W. Mather, Prof. Nat. Hist. in the Ohio University. 654 pp. 4to, with 46 plates, including a geological map. Albany, N. Y., 1843.

§ Agriculture of New York; by Ebenezer Emmons, M.D. Vol. i., being one of the Reports of the Geological Survey of the State, and lettered, on the cover, part v. Agriculture. 372 pp. 4to, with plates. Albany, N. Y., 1846. The chapter on the Taconic System covers pp. 45–112.

American Geology, by Ebenezer Emmons. Vol. i., 194 and 252 pp. 8vo, with 18 plates. Albany, 1855. Chapter on the Taconic Systems occupies pp. 1–124 of part ii.

Geological Report on the Midland Counties of North Carolina, by E. Emmons, 352 pp. 8vo, with 9 plates and several maps. New York, 1856. Chapters on the Taconic System occupy pp. 49–72.

satisfied himself so far as to the Taconic question, that on his Geological Charts, published in 1863 and 1869, he made the schists and associated rocks Lower Silurian, and of the "Quebec Group." In 1864 he made an examination of the Taconic and adjoining regions in company with Prof. James Hall*, visiting Berkshire and northwestern Connecticut, and extending his observations also west and south-west of the Taconic range to the Hudson river. The schists and limestones were found to be involved together in common folds, Canaan Mountain and Washington Mountain to be flanked with limestone, and to be probably synclinal in structure; and all were referred, with small exceptions, to the Quebec Group. The object of the exploration was the comparison of the rocks with some of those of Eastern Canada.

In 1861 the Geological Report of the State of Vermont, by Professor Edward Hitchcock, Mr. (now Professor) C. H. Hitchcock, his son, and Mr. A. D. Hager, was published†. It is an elaborate report, extending to 988 pages quarto, and containing numerous geological sections. On pages 251 to 257, Prof. Edward Hitchcock (the State Geologist, earlier, of Massachusetts) describes a section through the Taconic range, representing it as consisting of a series of *conformable* folded strata. On pages 595 to 682 Prof. C. H. Hitchcock gives the details with regard to thirteen sections across the State, coloured diagrams of which occupy three long folded plates. Seven of these sections cross the Taconic range; and in all but one of the seven the Taconic slates and the adjoining limestone (called in the Report the *Eolian* limestone) are made conformable. In a southern one of these sections, through the town of Bennington, the schists of Mt. Anthony, whose summit is 2688 feet in height above the mean tide-level, overlie the limestone in a shallow synclinal. In another section, passing through Arlington, and intersecting Spruce Peak, of the Taconic range, the same schists ("talcoid," or hydromica-schists) overlie in this peak the limestone in a still shallower synclinal, the limestone on the east dipping westward and that on the west dipping eastward at a small angle. In a third section, through Dorset and Dorset Mountain or Mount Eolus (3148 feet high), this mountain is shown to be made of limestone to within 500 feet of the top. These 500 feet consist of hydromica-schists; and they lie in the lap of the shallow limestone synclinal, conforming to it in bedding. The limestone of the mountain, crystalline, as elsewhere, and at several points quarried for marble, has a thickness over 1900 feet. In Mount Equinox, another Vermont peak of the Taconic range, 3872 feet in height, the limestone, according to the Report, rises as high perhaps as in Mount Eolus. The Report also reproduces Professor Emmons's section through Graylock, in Massachusetts, which

* Reported in a communication to the Natural-History Society of Montreal, Oct. 24, 1864, by Mr. T. Sterry Hunt, and published in the Canadian Naturalist and Geologist, and also in the American Journal of Science, second series, vol. xxxix. p. 96, 1865.

† Report on the Geology of Vermont. 2 vols. 988 pp., 4to, with a coloured geological map of the State and 38 plates, 1861.

represents it as a synclinal of schists underlain by limestone, the limestone outcropping on the east with a westward dip near South Adams.

The Report thus illustrates the conformability of the limestone and schists in various parts of the range through Vermont (south of Middlebury), and adds confirming facts from Massachusetts.

The Report also mentions the occurrence of fossils in the "Eolian limestone," near its junction with the schists, and principally from outcrops just west of them.

These fossils are stems of Crinoids, Cyathophylloid corals (referred incorrectly to the genus *Zaphrentis*), species of *Chætetes* and *Stictopora*, and a Gasteropod shell referred by Hall to *Euomphalus*. Prof. C. H. Hitchcock, in a note to me in 1880, describing his views and those of the Vermont Geological Report on this subject of the Taconic Schists, says (see American Journal of Science, volume xix. p. 237):—"There is nothing in the Vermont Report anywhere favourable to Taconism. Within the past two years I have gone over most of the Vermont sections, and have felt that they demonstrated the essential equivalence of the Taconic system with the Potsdam and the overlying limestones and slates [of the Lower Silurian]. I have been throughout in essential accord with you and Mr. Wing."

Mr. A. Wing, of Whiting and afterwards of Middlebury, Vermont, contributed some aid toward the Geological Survey of the State of Vermont (the Preface to the Report acknowledging "valuable facts and suggestions" from him, "a gentleman who had studied the geology of the State with great perseverance and success"). His conclusion was in harmony with that of the Report—namely, that the Taconic schists and limestone and the associated quartzite to the eastward were conformable Lower Silurian formations. Mr. Wing's researches were continued afterward until his death in 1875*. In 1866 he found *Trinucleus concentricus* and other Trenton fossils in the limestone of Sudbury, Vermont, just east of, or more properly within, the Taconic belt, and came to the conclusion that, since the limestone plainly dipped conformably beneath the Taconic Schists, the latter were younger than the Trenton—that is, equivalent to the Hudson-river slates, the last member of the Lower Silurian. Before the year 1872 (as may be found in my article in vol. xiii. of the American Journal of Science) his discoveries comprised various other Trenton fossils, besides species of the Quebec and Calciferous groups (as determined by Mr. Billings, of the Canadian Survey, to whom he sent his specimens), many of them from the limestone belt *west* of the Taconic, and many also from that to the *east*. Among the Trenton species discovered by him there are the common Cyathophylloid coral *Petraia profunda*, also *Receptaculites neptuni*, *Columnaria alveolata*, *Stenopora fibrosa*, *St. petropolitana*,

* See "An account of the discoveries in Vermont Geology of the Rev. Augustus Wing, by J. D. Dana," in the Amer. Journ. Sci., third series, vol. xiii. pp. 332, 405, and vol. xiv. p. 36, 1877.

Brachiopods of the genera *Orthis*, *Strophomena* and *Rhynchonella*, species of *Orthoceras*, besides the Trilobite *Trinucleus concentricus* "in great abundance." The species of the age of the Chazy limestone included *Pleurocystites tenuiradiatus*, a *Pleurotomaria* near *P. staminea* "in crowded abundance," *Bathyurus Angelini*, and *Asaphus canalis*. Those referred to the Quebec group comprised large *Maclureæ*, a species of *Rhynchonella* (some beds at East Cornwall full of their shells), *Bathyurus Saffordi*. Those of the Calciferous beds were *Ophileta compacta*, *O. complanata*, *Maclurea sordida*, *M. matutina*, small species of *Orthoceras*, the Trilobite *Bathyurus conicus*, and others.

As these species of the Trenton group and of the older Chazy, Quebec, and Calciferous groups were collected from different localities in one and the same limestone mass or formation, Mr. Wing arrived at the very natural conclusion that (I quote his own words from a letter of May, 1875):—"The Eolian limestone of the Vermont Geological Report embraced not only the Trenton and Hudson-river beds, but all the formations of the Lower Silurian as well, and even limestones and dolomites of the Red-Sand-rock [Potsdam Sandstone] series." These were his views as early at least as 1872. In this fact the limestone is like that of the Mississippi basin; for there, too, a single limestone formation, with but small interruptions, covers the eras of the Lower Silurian continuously from the Calciferous (if not the Primordial) to the Trenton inclusive.

Thus all investigators of the Taconic belt and the associated rocks, Professor Emmons included, have found the limestones and schists one in stratification and one in system. The only differences are these:—

Professor Emmons made the Taconic schists intermediate in age between the two limestones and the western limestone, therefore the oldest, because, as he says, this was the order of superposition, the dip of the whole being eastward. He states on page 147 of his Report of 1842:—"So long as the more western belt by this rule is the inferior limestone, there is no necessity in the case to suppose a series of complicated changes in order to make it coincide with conjectures."

Sir William Logan was led by his studies to regard the schists and limestone strata as together of the Quebec group.

The Professors Hitchcock referred the rocks to the Lower Silurian, and recognized the Taconic schists as the youngest of the series.

Mr. Wing concluded that all the periods of the Lower Silurian were represented in the limestone, down to the Primordial and up to the Hudson-river group, and that the Taconic schists were the youngest, and of the Hudson-river group. The same general conclusion was adopted theoretically by the Professors W. B. and H. D. Rogers in 1841, and by Prof. Mather in 1843.

The quartzite formation, which accompanies the eastern limestone belt in Vermont, Massachusetts, and Connecticut, was made by Prof. Emmons a member of his Taconic system, conformable to

the other members, in his earliest as well as later publications on the subject; and each of the other geologists above mentioned has referred it to one and the same conformable series with the schists and limestones. Prof. C. H. Hitchcock and Mr. Wing have urged strongly that it was the probable equivalent of the Potsdam sandstone.

I have not included thus far any notice of observations by Dr. T. Sterry Hunt in the region of the Taconic mountains and the adjoining limestone, because he has published none on the subject. In 1871, in his Address before the American Association*, he referred the Taconic schists and limestone to the Lower Silurian, making the limestone east of the Taconic range of the age of the Quebec group, as done by Logan, and stating that the conclusion of Rogers and Mather, referring the Taconic system to the "Champlain Division" [Lower Silurian] of the New-York series, had been sustained by subsequent observations. The same opinion essentially he had presented at various times since 1849. In 1878, but four years since, appeared Dr. Hunt's first published statement, so far as I have been able to learn, dissenting from his earlier views †; and in it he calls the system the *Taconian*, and makes the *Lower* Taconian to be an equivalent of the lowest Cambrian, or still older, resting his proof *not* on any stratigraphical observations in the region of the Taconic schists. In his recent announcement of his opinion before the Geological Society, on the 16th of last November, he says, speaking of the Taconian, Montalban, and Huronian systems, all these various series are older than the Lower Cambrian (Menevian) strata of North America; and his argument against the stratigraphical evidence as to age and conformability, which had been presented by others, is met only by the expression of a doubt, and the reason for it above cited.

My own detailed study of these Taconic schists and the associated rocks commenced in 1870, before the discoveries of Mr. Wing had been made known; and they have been continued through portions of most of the seasons since that time. They have extended over a large part of the Green-Mountain and Taconic area, from Middlebury in Vermont to New York City, and westward through Dutchess and Westchester Counties, in Eastern New York, to the Hudson river‡.

* Address to the American Association for the Advancement of Science, by Thomas Sterry Hunt, on retiring from the office of President of the Association, August 1871.

† Proceedings of the Boston Society of Natural History, vol. xix. p. 275, 1878; Pennsylvania Geological Report on Azoic Rocks, part i. 1878.

‡ "On the Quartzite, Limestone, and associated Rocks of the vicinity of Great Barrington, Berkshire Co., Mass.," Amer. Jour. Sci. 3rd ser. vol. iv. p. 362, 450, 1872, v. p. 47, 84, vi. 257, 1873; "On the Relations of the Geology of Vermont to that of Berkshire," *ibid.* vol. xiv. pp. 37, 132, 202, 257, 1877; "On the Hudson-River Age of the Taconic Schists and the dependent Relations of the Dutchess-County and Western Connecticut Limestone Belts," *ibid.* vol. xvii. p. 375, vol. xviii. 61, 1879; "Note on the Age of the Green Mountains," *ibid.* vol. xix. p. 191, 1880; "On the Geological Relations of the Limestone Belts of Westchester County, New York," *ibid.* vol. xx. pp. 21, 194, 359, 450, (1880), vol. xxi. p. 425, vol. xxii. pp. 103, 313, 327, 1881.

The results arrived at sustain those of the several investigators mentioned in proving (1) that the Taconic schists and the adjoining limestones, as well as quartzite, are *one in system of stratification*, and (2) that they have in general *a high eastward dip*.

In 1875 I traversed with Mr. Wing the region of his explorations in Vermont, saw the fossils in the metamorphic limestone at some of their localities, and found that his palæontological demonstration (1) of the Lower-Silurian age of the limestone, and (2) of its covering the periods of the Lower Silurian from the Trenton to the Calciferous inclusive (if not also the Primordial), was complete. I was shown also (3) that this demonstration from fossils had been obtained both from the limestone on the *east* and that on the *west* side of the Taconic belt, proving that they were alike in geological age, and therefore parts of the same great limestone formation—a fact apparent also in their joining and becoming one mass near Middlebury, Vermont. I was convinced, further, that the stratigraphical facts left no reasonable doubt as to the limestone formation being inferior in position to the Taconic schists.

In my observations among these rocks over the region extending from Vermont through Massachusetts, I aimed chiefly at tracing southward the evidence as to the continuity and unity in system of the Taconic and associated formations; for the beds were too highly crystalline to contain fossils, though not so highly but that I looked for them at some of the more favourable localities. Besides finding a general eastward dip along the region in the schists and the limestone of this eastern side of the Taconic belt, I discovered also that in South-western Massachusetts, where the Taconic belt is widened to treble its usual breadth, and rises into the high mountain region called Mount Washington—its highest point 2634 feet above the sea—there the limestone and schists dip *westward*, the limestone passing beneath the schists; and hence, inasmuch as the dip on the west side of the range is eastward, they apparently gave proof of a synclinal, just such as is afforded by several mountain-summits of the Taconic range to the north—Mounts Anthony, Spruce, Dorset, and others in Vermont. Mount Washington is continued southward through North-western Connecticut; and in this part also the same evidence of a synclinal—a westward dip on the east, and eastward on the west—was obtained.

To the west of the northern half of the State of Connecticut, the Taconic schists and the adjoining western limestone extend south-westward, over Dutchess County, New York, to the Hudson river. As they spread westward, the schists and limestone become less and less crystalline, and hence are in a more and more favourable condition for the preservation of the original fossils of the rocks. In 1879, while pursuing my investigations over this county, I found fossils of Trenton age at Pleasant Valley in this western limestone, about a dozen miles west of the Taconic belt, and subsequently obtained other fossils from points half nearer the belt. Professor W. B. Dwight, of Poughkeepsie (in Dutchess County, on the Hudson river) was with me at the first discovery, and has since extended

greatly the range of localities and fossils. The species include well-known Trenton Brachiopods (*Orthis lynx*, *O. pectinella*, *Rhynchonella capax*, *Leptæna sericea*, *Strophomena alternata*) and Corals (*Petraia corniculum*), the Trenton Receptaculites, Crinoids, *Orthocerata*, and Trilobites (*Illænus crassicauda*). But besides Trenton species, Prof. Dwight has obtained from portions of this same limestone belt or formation, and at two places within a few rods of Trenton fossils, fossils of the Calciferous group, embracing several species of small *Orthocerata* (among them *O. primigenium*) and of *Ophileta* (*O. complanata* and *O. levata*, *O.* (*Maclurea*) *sordida*), &c. At another locality in the continuation of the limestone west of the Hudson, the Chazy species (*Maclurea magna*) has been found by the palæontologist, Mr. R. P. Whitfield.

It has thus been proved that the *western* of the limestones associated with the Taconic schists (the Sparry limestone of Emmons) consists, to the south, in Dutchess County, of the combined limestones of the Calciferous, Chazy, and Trenton eras, just as it does to the north, in Vermont.

Less than a year before this discovery of fossils in the limestones of the Dutchess County, Mr. T. Nelson Dale had announced his discovery of related fossils in the hydromica-schists adjoining the same limestone near Poughkeepsie. The species were *Orthis testudinaria*, *O. pectinella*, *Leptæna sericea*, *Strophomena alternata*, and remains of Crinoids; and Mr. Dale announced the schists to be of Hudson-river age or newer than the Trenton. Both these Poughkeepsie schists and the associated limestone Prof. Emmons had referred, by a special mention of the locality, to his Taconic system.

The discovery of fossils in the limestone was a natural sequel to that of those in the schist; and together they made the evidence positive that the limestone and schist are Lower Silurian, and the schist the younger formation. The result was hence reached alike from the rocks from the southern end of the Taconic belt and from those of the northern or Vermont end. It is sustained in both regions by an abundance of determinable fossils as well as by the stratification. If Prof. Emmons's view is right with regard to the western and eastern limestones and the intermediate Taconic schists that the order of superposition is the order of age, then the *western* is the oldest of the three, and consequently the Taconic schists beneath which it dips are younger than the Trenton schists, inasmuch as the western limestone is partly of Trenton age. But it makes the eastern limestone younger still, or a part of the Hudson-river group.

Facts prove, however, that the eastern and western limestones are the same formation flexed together, and that this limestone formation in some plain cases underlies the schists, all being manifestly in a broad shallow synclinal. And hence, in the part of the Taconic range having only eastward dips, the probable conclusion, taking into view all the facts from the fossils, is that the beds lie in general in a closely compressed synclinal. Eastward dips, as has been remarked, prevail along the range; the broad and shallow synclinals

exist where the high and broad mountain masses occur, and are apparently the occasion of both the breadth and the height.

These are, in brief, the facts relating to the stratification of the Taconic schists and limestones, and to the palæontological evidence of their age. For the details I refer those interested to the works and memoirs that have been already mentioned.

I have not said, nor do I believe, that all the hydromica-schists west of the Taconic range that have been referred to the Taconic system, and first by Emmons, are equivalents of the Hudson-river group. Part are unquestionably Primordial, as their association with the underlying quartzite proves. But that this is the age of the chief part of the schists of the Taconic range appears to be established both stratigraphically and palæontologically.

The occurrence of hydromica-schists with the quartzite, and their interstratification, I have observed to be a common fact in Vermont, where the quartzite is largely developed, as well as in Dutchess County, where it is sparingly found. The area marked as quartzite on the coloured geological map of the Vermont Geological Report really consists of both rocks, but with the quartzite greatly predominating in some parts.

In connexion with this paper on the Taconic system, I send also to the Geological Society a map of New England (a portion of the State of Maine excluded) on which is shown the position and general arrangement of the Taconic schists and the associated limestones of Western New England and Eastern New York (Pl. XVII.) It will be found to be a weighty argument of itself for the essential unity in system of the rocks referred to. The Archæan enters into the area from the State of New Jersey on the west (where it constitutes the "Highlands"), covers nearly all of Putnam County, and occurs in isolated areas in Connecticut, Massachusetts, and probably, as held by Prof. C. H. Hitchcock, in Vermont, east of that of the quartzite. The quartzite I believe now to be mainly, if not wholly, Primordial, and to rest unconformably on the Archæan rocks, whenever the two come in contact.

The map also shows the position of unaltered Lower Silurian rocks west of the north end of the Taconic range, in Central Vermont. The Red Sand Rock has been proved by fossils to be Primordial; and if the quartzite on the east (with the interstratified hydromica-schist) is also Primordial, then the two are the same formation. The next formation to this Red Sand Rock on the west is the Hudson-river Group, the beds lying against those of the Red Sand Rock in consequence of a prolonged fault, the existence of which was first indicated by Sir William Logan.

The sources referred to for the outlines of the areas of Taconic schists and the associated limestones laid down on the map are, for the States of Vermont and Massachusetts, the coloured maps accompanying the Geological Reports of those States; and for Dutchess, Putnam, and Westchester Counties, New York, my own maps, as published in my papers. Some corrections for the Vermont part have been made from a small map by Mr. Wing, and slight changes

for that of Massachusetts from my own observations. The maps of Vermont and Massachusetts could be much improved by a more thorough survey; but the changes that would be thus introduced would not alter the general facts bearing on the Taconic question.

A word further with regard to the paragraph cited in the early part of this paper from the Proceedings of the Geological Society.

This paragraph makes the stratigraphical evidence doubtful, because it says, "where newer strata are in unconformable contact with older ones, the effect of lateral movements of compression, involving the two series, is *generally* to cause the newer and more yielding strata to dip towards and even beneath the edges of the older rock."

The fact here alleged may be questioned. But letting it stand that, under the conditions stated, the newer and more yielding strata are generally made to dip toward the older rock, it has no bearing here; for there is no such general dip along the Taconic range. The limestone of its eastern side, here claimed to be the newer, *does not generally dip toward the older rock*, that is, toward the Taconic schists, which are claimed to be the older. Through nine tenths of the length of the belt, the dip, as all observers have found, and as recognized above, is eastward for both the eastern limestone, the schists, and the western limestone, the westward dip of the eastern limestone occurring, as has been stated, in the region of the higher peaks. Hence the point *insisted* upon by the propounder of the doubt, if true in fact, has no application to the region of the Taconic schists.

The stratigraphical and palæontological demonstration of the Lower Silurian age of the Taconic and associated rocks leads us to conclusions of lithological interest. It enables us to decide definitely what are some of the kinds of metamorphic rocks that may be of Lower Silurian age, and of the closing period of the Lower Silurian; for the Taconic schists, which are in part roofing-slates at the northern extremity of the range in Vermont, where the metamorphic changes were slight, are, a little to the south, hydromica-schist; and further south, chloritic hydromica-schist and chlorite-schist, as well as ordinary hydromica-schist, each kind often granatiferous; and then, still further, mica-schist, generally granatiferous and in some places staurolitic; and at the southern extremity they are in part mica-schist and gneiss. Such facts bear weightily on the lithological criterion of geological age in its application to metamorphic rocks; and perhaps some will recognize in this a reason for the expression of that doubt remarked upon above.

I leave the lithological branch of the subject with this single remark, referring to my papers on the limestone and associated rocks of the Green Mountains for further details.

EXPLANATION OF PLATE XVII.

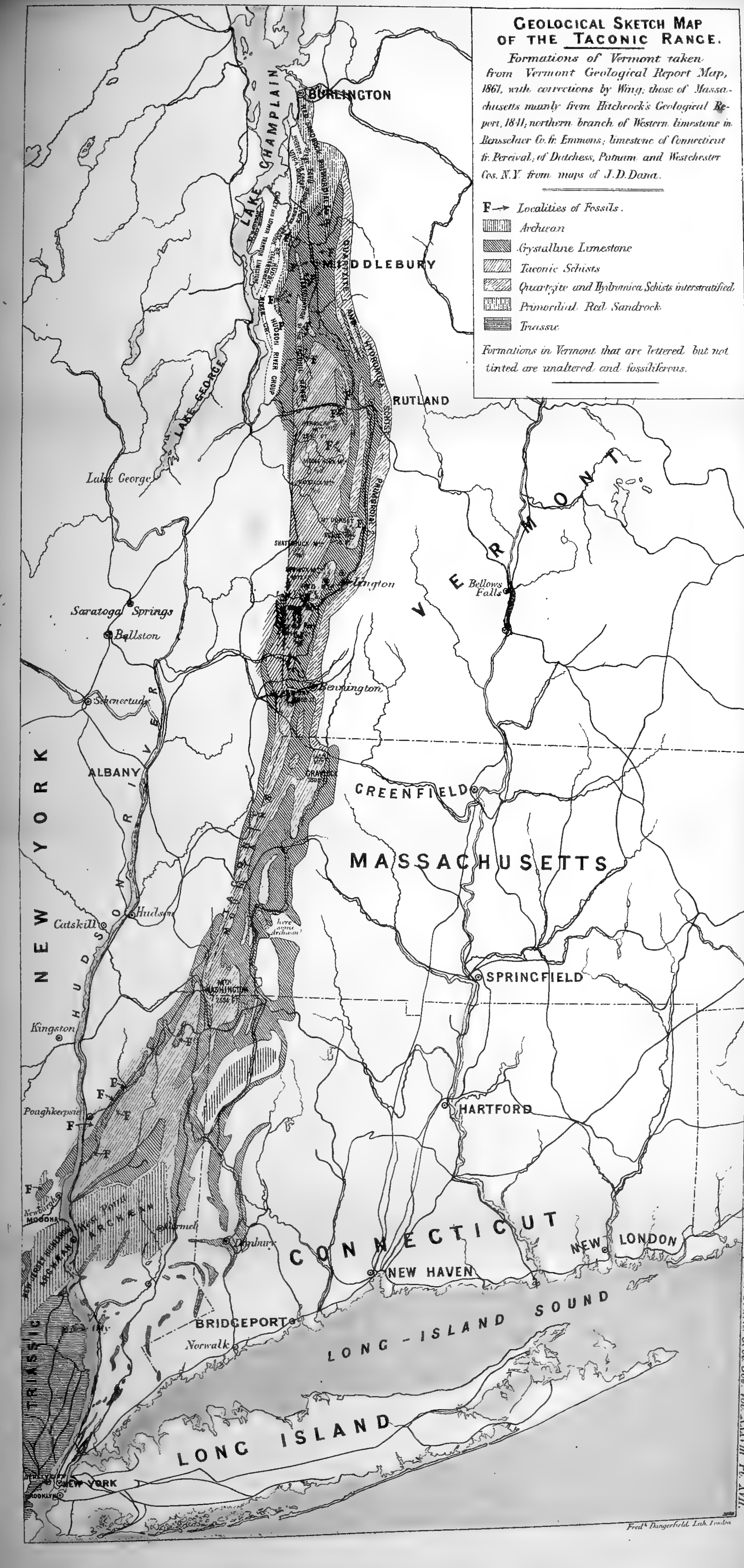
Geological Chart of part of Western New England and Eastern New York, representing the areas of the Taconic schists and the associated limestones and quartzite. The blank area to the east is occupied mainly by gneiss and mica-schist; and that to the west, for the most part by the semicrystalline schist, argillite, and hydromica-schist. The quartzite formation extends south of the area so marked, through Massachusetts into Connecticut; but the areas of quartzite being small and not yet accurately mapped, they have been omitted.

Discussion.

Dr. Hicks remarked that the Taconic controversy greatly resembled that going on in this country with regard to the rocks of the North-west Highlands. In the absence of Dr. Sterry Hunt he must oppose the views enunciated by Prof. Dana. He thought that the disturbed rocks of North Wales explained clearly how newer strata were continually made to appear to dip under the older ones, and the evidence generally quite bore out the views of Dr. Hunt.

Prof. Duncan stated that the Society received with great pleasure this paper from a great master of geology. Prof. Dana described the country as not greatly disturbed by faults. He was inclined to accept the idea that metamorphism may have gone on during any part of the earth's history.

Prof. Judd, in the absence of Prof. Dana, stated that that author used the term Silurian in the same sense as M. Barrande and the late Sir Roderick Murchison. He admitted that the limestone series contained fossils which proved them to represent the whole series, from the Primordial up to the Upper Silurian. He had also distinctly stated that a number of Lower Silurian fossils had been found not only in the limestones but also in the schists, and in schists which had been expressly stated by Emmons to be a portion of his Taconic system.


GEOLOGICAL SKETCH MAP
OF THE TACONIC RANGE.
Formations of Vermont taken from Vermont Geological Report Map, 1861, with corrections by Wing; those of Massachusetts mainly from Hitchcock's Geological Report, 1841; northern branch of Western limestone in Rensselaer Co. fr. Emmons; limestone of Connecticut fr. Percival; of Dutchess, Putnam and Westchester Cos. N.Y. from maps of J. D. Dana.
F→ Localities of Fossils.
Archæan
Crystalline Limestone
Taconic Schists
Quartzite and Hydromica Schists interstratified.
Primordial Red Sandrock
Triassic
Formations in Vermont that are lettered but not tinted are unaltered and fossiliferous.
BURLINGTON
LAKE CHAMPLAIN
MIDDLEBURY
QUARTZITE AND HYDROMICA SCHIST
PRIMORDIAL
RUTLAND
HUDSON RIVER GROUP
LAKE GEORGE
Lake George
VERMONT
Bellows Falls
Bennington
Saratoga Springs
Ballston
Schenectady
ALBANY
NEW YORK
HUDSON RIVER
Catskill
Hudson
Kingston
Poughkeepsie
Newburgh
CREENFIELD
MASSACHUSETTS
SPRINGFIELD
HARTFORD
CONNECTICUT
NEW HAVEN
NEW LONDON
BRIDGEPORT
Norwalk
LONG-ISLAND SOUND
LONG ISLAND
NEW YORK
BROOKLYN
TRIASSIC
ARCHÆAN
Fred^k Dangerfield Lith. London

42. *On the* MADREPORARIA *of the* INFERIOR OOLITE *of the* NEIGHBOURHOOD *of* CHELTENHAM *and* GLOUCESTER. By ROBERT F. TOMES, Esq., F.G.S. (Read May 10, 1882.)

[PLATE XVIII.]

INTRODUCTION.—In 1878 I made known through the pages of the Geological Magazine* some genera of Madreporaria from the Inferior Oolite of Crickley Hill, Gloucestershire, which, although not new, were nevertheless not only new to the beds under consideration, but also to this country; and I at the same time increased the number of species from that locality, observing that the paper would serve as a basis to which additions and corrections could from time to time be made.

Since then a very extensive series of corals from the Inferior Oolite of Gloucestershire has come into my hands, and has enabled me to add very greatly to my previous paper, not only in the number of species, but by the addition of genera not hitherto recognized as appertaining to the Oolite of England.

I have also, by the acquisition of more abundant material, been able to correct some errors into which I, as well as others, had fallen, and to reduce some of the hitherto acknowledged species to the position of synonyms only. The list of species I am now enabled to give is rather remarkable for the great number of genera as well as species it contains which are peculiar to the locality. But when we remember the number of new forms discovered by MM. Edwards and Haime from the very limited collection submitted to their inspection, we need not be surprised that, with the advantage of much more abundant material from the same locality, the coral-fauna should prove to be very distinct from that of other corallian deposits of the Inferior Oolite.

In a paper by M. Milaschewitsch, published in the 21st volume of the 'Palæontographica'†, mention is made, at page 194, of a process of intermittent development which is very conspicuous in the *Montlivaltiæ* and observable also in some other genera, and which must here be explained. According to that zoophytologist, the corallum, under certain unknown conditions, can almost suddenly contract itself, and afterwards more or less quickly expand again and continue its existence in a new form. This M. Milaschewitsch distinguishes by the name of Verjüngungsprocess, which may be translated into a "process of *rejuvenesence*." This rejuvenescence takes place in very different degrees and manners. Sometimes it leaves behind on the corallum only slight marks or step-shaped constrictions; but in other cases the constriction is much more strongly marked, so that the new form is perhaps only connected with the

* Vol. v. July 1878.

† Die Korallen der Nattheimer Schichten.

old calice by a footstalk; and it may be in the centre of the calice, or on one side.

In the first case, that is when central, only the septa of the first rank pass over, and they pass equally on all sides into the new calice. In the second, on the side opposite to the one where the constriction has taken place, all the septa of the old individual pass into the new one, whilst on the constricted side only the septa of the first rank pass in.

This process, M. Milaschewitsch observes, has the greatest relationship to that of division, because a portion of the organs of the old individual pass into the young one, though there is no addition to the number of individuals. From calicicular budding it is quite distinct; for where that takes place the destruction of the old individual occurs, and one or more entirely new ones take its place. This is the case with the Rugosa: but it must not be confounded with rejuvenescence, as explained in the paper I have here referred to.

In this important paper, and in one which accompanies it by Dr. E. Becker, the structure and natural affinities of a number of obscure Madreporarian forms are examined, and their relations made clear.

When drawing up descriptions of corals, as well as when applying published descriptions to the specimens themselves, I have often found occasion to regret that the reference to one part of their structure was not more descriptive and exact. The *costæ* are met with on such very different parts of the corallum, and are themselves so variable in character, that I have for a long time past, for my own convenience, classified them as follows:—

Mural costæ, or those which appear on the wall of the corallum, whether it be that of a simple or compound species, as, for instance, in *Parasmilia* or *Latimæandra*.

Septal costæ, or those which are a continuation of the septa, and not distinguishable from them, as in *Thamnastræa* and *Holocœnia*.

Intercalicular costæ, or those which cover the cœnenchyma between the calices of some compound species, as in *Stylina* and *Cyathophora*.

The first of these, the mural costæ, appear on the basal wall or plate which, in many compound species, is common to several corallites, and on the investing wall of the simple forms. In either case they hold a distinct and very close relationship with the wall. But the only connexion which the second kind of costæ hold with the wall is by passing over its superior margin transversely onto the exotheca; while the third kind of costæ do not necessarily come into contact with the wall at all, and if they do, it is only one end which abuts against it. But, indeed, the intercalicular costæ are often represented by tubercles or papillæ, which perhaps may not be costæ at all. No precise name has yet, so far as I know, been given to these varieties of costæ, except those I have here called the septal costæ, which are usually spoken of in connexion with the septa as the septo-costal rays, a name which is very objectionable, as not, in some instances, applying to the parts under consideration. For instance, in

many *Thamnastrææ* the costæ are placed parallel to each other, and cannot properly be called rays. In other instances, again, they anastomose, or are very flexuous, and can scarcely be made to come within the definition of rays.

Stratigraphical Distribution of the Species.

As long ago as 1866 Dr. Wright made known, in the 'Proceedings of the Cotteswold Naturalists' Field Club,' the existence of three well-defined coralliferous deposits in the Inferior Oolite of Gloucestershire, and gave their exact stratigraphical position, the localities where they could be observed, and as far as the material then at command would permit, the species of Madreporaria they contained.

Frequent search in these beds within the last few years has enabled me to greatly extend the list of species, and to refer them to the respective beds to which they belong, with greater accuracy than could before be done.

I give the stratigraphical distribution of the species, arranged in a tabular form (p. 413), taking Dr. Wright's three coral-reefs as my basis, but first adding some observations thereon.

A few corals are seen scattered about in the Pisolite and in the compact yellow stone beneath, lying between it and the Cephalopoda-bed, which latter is regarded by Dr. Wright as the upper bed of the Upper Lias. One species, *Montlivaltia lens*, occurs in both the compact yellow stone and in the underlying Cephalopoda-bed, and it is the only coral I have met with in the latter deposit. These are the lowest representatives of coral life in the Jurassic seas of England, with the exception of the Liassic species*.

The Lower Reef of Dr. Wright lies directly upon the Pisolite, and it has all the appearance and character of a true reef. It consists of a fine-grained cream-coloured stone which is sometimes soft enough to be removed from the fossils with a hard brush.

Specimens of corals so cleaned have often all the sharpness and delicacy of their parts preserved, and are almost as easy to study as recent specimens. But more frequently the bedding is so hard that it cannot be removed even with the aid of the graver. It is in this reef that the corals are most abundant; indeed in some places, as at Crickley Hill, they may be said to constitute the chief part of its bulk.

There is every appearance in the lower coral-bed of the corals having lived and died where they are now found; for many old and dead examples are there seen, to which other corals and Serpulæ of delicate structure have attached themselves, and have retained their beauty up to the present time.

The Middle Reef is in the oolite marl, a fine-grained chalky deposit. In corals it is by no means so rich as the lower one, either as regards the number of the species, or the abundance of

* By the Liassic species I mean those which occur in the Lias proper, and not those which have an equivocal place at the bottom of the formation, and are probably Triassic. I allude more particularly to those from the Sutton Stone of Glamorganshire, which I have always regarded as Rhætic species.

those which do occur. In fact it hardly merits the name of reef, being in some localities uncoralliferous, while in others the corals are rare. At the Horse Pools, Brookethorp, near Gloucester, where the lower reef is pretty well developed, the oolite marl, though present, and also by no means poorly developed, is not coralliferous. Near Ravensgate Hill, in the neighbourhood of Charlton Kings, there is an exposure of oolite marl which is, too, destitute of corals. But at Leckhampton, where also it can be well studied, the corals are tolerably abundant, but they are there confined to patches. The oolite marl also occurs and is coralliferous at Sheepscombe and Painswick.

Although, however, it is by no means well stored with corals, it has some which are peculiar to it; they are *Phyllogyra sinuosa*, *Latimæandra tabulata*, *L. Haimei*, and *Oroseris incrustans*. *Donacosmilia Wrighti*, *Montlivaltia Painswicki*, *M. tenuilamellosa*, *Confusastræa consobrina*, *Anabacia complanata* and *Thamnastræa Lyelli* pass upwards into it from the lower reef.

The Upper Reef is in the lower *Trigonia*-grit, which is a deposit quite unlike either of the other coral-beds here mentioned. It is of a yellow colour and scarcely oolitic, and contains many indurated smooth lumps, which evidently had their present form before deposition, as parasitic shells and young *Montlivaltiæ* are often found attached to them.

With the exception of *Anabacia complanata* and *Thamnastræa mettensis*, which species also occur in the lower bed, this upper coral-deposit has its own species quite distinct from those of the middle and lower ones. It is well exposed at Leckhampton, Ravensgate, Birdlip, and Brown's-Wood hills.

The corals occur for the most part quite at the bottom of the *Trigonia*-grit, some of them even appearing to have actually grown upon the bed below: but others have much the appearance of having been derived from some other place not far removed. The large so-called *Thecosmilia gregaria*, which is peculiar to this horizon, probably furnishes evidence to this effect; for while peduncular and therefore more or less globular specimens are common, older and branching ones are very rare. Probably those which were most easily removed are the ones now met with in the greatest plenty; but they cannot have come from any distant spot, or they would exhibit evidences of rolling. Possibly the exposures of this coralliferous deposit were in the immediate neighbourhood of a reef, but they certainly have not the aspect of a reef proper.

It is worthy of remark that no branching corals have yet been met with in this bed; and perhaps their absence, and the presence of rounded and smooth species of *Isastrææ* and *Thamnastrææ* (which, of these genera, are alone observable) may furnish further evidence of their derivative origin, from the ease with which they would be removed.

It will be seen that all the *Montlivaltiæ* of this upper coralline deposit are quite distinct from those of the other two.

In the following Table, column No. 1 contains the species from

the Pisolite and the beds below it, No. 2 those from the lower reef, No. 3 those from the middle reef, and No. 4 those from the upper reef:—

	1.	2.	3.	4.
Epismilia, sp.	...	...	...	*
——, sp.	...	...	...	*
Donacosmilia Wrighti	...	*	*	
Montlivaltia tenuilamellosa	*	*		
—— Morrisi	...	*		
—— Painswicki	...	*	*	
—— Wrighti	...	*		
—— trochoides	...	*		
—— cupuliformis	*			
—— lens	*			
—— Smithi	...	...	...	*
—— concinna	*			
—— porpita	...	...	...	*
——, sp.	...	...	...	*
——, sp.	...	...	...	*
——, sp.	...	...	...	*
Cyathophyllia oolitica	...	*		
——, sp.	...	*		
Thecosmilia Wrighti	...	*		
—— ramosa	...	*		
Confusastræa consobrina	...	*	*	
—— tenuistriata	...	*		
Isastræa serialis	*			
—— tenuistriata	...	...	...	*
—— depressa	...	*		
Latimæandra Flemingi	...	*		
—— Davidsoni	...	*		
—— tabulata	...	...	*	
—— Haimei	...	...	*	
Chorisastræa rugosa	...	*		
—— ? gregaria	...	...	...	*
Phyllogyra Etheridgii	...	...	...	*
—— sinuosa	...	...	*	
Goniocora concinna	...	*		
Thecoseris polymorpha	...	*		
Anabacia complanata	...	*	*	*
Thamnastræa crickleyensis	...	*		
—— Duncani	...	*		
—— Manseli	...	...	...	*
—— Lyelli	...	*	*	
—— Wrighti	...	...	...	*
—— flabelliformis	...	*		
—— fungiformis	...	...	...	*
—— mettensis	...	*	...	*
—— Defranciana	...	*		
—— Terquemi	...	*		
—— Walcoti	...	*		
Microsolena porosa	...	*		
—— regularis	...	...	...	*
——, sp.	...	*		
Oroseris oolitica	*			
	6	29	8	16

	1.	2.	3.	4.
	6	29	8	16
Oroseris concentrica	...	*		
—— contorta	...	*		
—— incrustans	...	...	*	
—— gibbosa..................................	...	...	...	*
Dimorpharæa Lycetti	...	*	*	
—— pedunculata..............................	...	*		
—— Fromenteli	...	*		
——, sp.	...	*		
Phylloseris rugosa	...	*		
——, sp.	...	*		
Comoseris vermicularis	...	*		
	6	38	10	17

A glance at the foregoing Table will at once show, from the small number of species which are common to the three coralliferous beds, that their connexion with each other is not very intimate. There is, however, a certain relationship between the lower and middle ones, as many as six species out of forty-eight being common to both.

Into the upper coral-bed, however, two species only from the lower bed pass ; and the importance of one of them is much lessened by the fact that it has a much more extended range in time, and is common in the Great as well as in the Inferior Oolite. It is *Anabacia complanata*. The other one, *Thamnastræa mettensis*, is much more abundant in the upper than in the lower coral-bed, as well as being of much more vigorous growth ; it has not yet been met with in the middle reef to the best of my knowledge.

The species here given, their distribution in time, and the growth and development of the individuals will at once show that the conditions favourable to the production of simple species were wanting, not only in the lowest beds, which are only a little above the Upper Lias, but also in the overlying lower reef: for while such species as *Isastræa serialis* and *Oroseris oolitica* had a vigorous growth and attained to a considerable size, the *Montlivaltiæ* were dwarfed and distorted in form. The same observation will apply in a great degree to the species in the lower reef. The simple corals found in it are mostly small and irregular in growth, while the compound ones are well formed and vigorous. In a word, the reef-builders throve, while those which were not reef species exhibit great poverty of development.

Only two simple corals occur in the middle coral-bed, and they are continued into it from the lower one. They are the *Montlivaltia Painswicki* of Prof. Duncan and *Anabacia complanata*.

In the upper coral-bed, however, are several *Montlivaltiæ*, and they are of more regular and less interrupted growth, as well as of larger size, than those of the inferior deposits. They less strictly resemble the species of a true reef than those before mentioned.

Description of the Genera and Species.

In the number and variety of the species, these coralliferous beds of the Inferior Oolite furnish interesting material for research. Several genera are now for the first time made known as occurring in the Jurassic formation of this country, some of which have not heretofore been recorded as appertaining to this or any other English formation.

Donacosmilia, hitherto known to have been met with only in the corallian of France, appears and is common in the lower and middle coral-beds at both the Crickley and Leckhampton Hills.

Confusastræa has also been met with in the same beds and at the same places.

Cyathophyllia and *Dimorphastræa* I introduced into the English list in 1878, and the introduction of one has been confirmed by the acquisition of additional specimens, while the other proves to be a species of *Dimorpharæa.*

Oroseris, up to this time known as an English genus only by an unsatisfactory fragment from the Upper Greensand of Haldon *, is now represented by several well-marked species.

Dimorpharæa, established by M. de Fromentel in 1858–61 †, is represented by four.

To complete the list of genera, the discovery of which has so much altered the whole *facies* of the coral-fauna of the Inferior Oolite, I must now mention two which I have found it necessary to create for the reception of certain corals which could not satisfactorily be placed with those of any recognized genera.

One of them is a genus of the compound Astræidæ, to which I have given the name of *Phyllogyra.*

The other is one of the Poritidæ, and is here named *Phylloseris.*

ZOANTHARIA APOROSA.

Family *ASTRÆIDÆ.*

Subfamily Eusmilinæ.

Genus Epismilia, *de From.*

Epismilia, sp.

A single example of a small turbinate coral was found by me in the *Trigonia*-grit at Ravensgate Hill, which, though not in a sufficiently satisfactory state of preservation to admit of description, is nevertheless referable to the genus *Epismilia.*

The edges of the septa have been worn off, but all of them have their sides quite smooth. The principal ones retain their size until they approach the greatly elongated fossula, when they become attenuated, much curved, and, crossing the central line, interlace, but do not blend with each other.

The dissepiments are strongly developed and numerous, and placed

* Prof. Duncan, Quart. Journ. Geol. Soc. vol. xxxv. p. 89.

† Introd. Etude Polyp. Foss. p. 254.

so as to present much the appearance of a series of rudimentary inner walls, somewhat as in *Circophyllia*. The central part of the calice is quite free from dissepiments.

I have not before seen the peculiar arrangement of the septa in the visceral region which is so apparent in this coral.

EPISMILIA, sp.

Several specimens of a species quite distinct from the last have been taken from the same locality and from the same bed, which appear to differ from *Montlivaltiæ* in having smooth septa, which are alternately thick and very thin. They have elongated fossulæ, but the septa do not interlace, and the dissepiments are feebly developed and not distributed as in the former species.

Genus DONACOSMILIA, *de From.*

DONACOSMILIA WRIGHTI, Edw. and Haime, sp.

Axosmilia Wrighti, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 128.

Montlivaltia Holli, Dunc. Supp. Brit. Foss. Cor. pt. iii. p. 16, pl. 1. figs. 5–8 (1872); Tomes, Geol. Mag. dec. ii. vol. v. 1878.

Portions of a branching coral are very common in the lower and middle reefs of several localities in Gloucestershire. These, by comparison with specimens of *Donacosmilia corallina* received from M. de Fromentel have been satisfactorily determined as appertaining to that genus. It is characterized by growth by lateral gemmation, and by septa which have their margins entire. It is most frequently met with in single joints, which may show periods of growth or not. These have been respectively described by Prof. Duncan as *Montlivaltia Holli*, and by MM. Edwards and Haime as *Axosmilia Wrighti*. The latter specific name must have the precedence.

It will not be necessary to add to the descriptions already published by those zoophytologists, excepting to state that it is a tall species, the branches of which are united to the larger stems by so small a point of attachment that they are readily broken off, and the acquisition of any thing like complete specimens, except when imbedded in matrix, is very difficult.

This species occurs commonly in the lower reef at Crickley Hill, the hill above the Horse Pools, and near Cooper's Hill, and in the middle reef at Leckhampton Hill and Painswick; but I have not yet met with a single fragment from the upper reef.

I am indebted to Dr. Wright for the opportunity of examining the types of *Axosmilia Wrighti*, and to Dr. Holl for the use of the specimens of *Montlivaltia Holli*, figured and described by Prof. Duncan. The comparison of numerous specimens with these leaves no doubt as to the correctness of my determination.

Since the publication of my paper on the Crickley Corals, I have entertained great doubts whether the species there referred to, the *Thecosmilia Wrighti* of Duncan, was any thing more than portions of *Donacosmilia Wrighti* which had attained to a greater size than usual; and I was led to entertain that suspicion in consequence of

some indications of lateral gemmation. But I have since met with some specimens which appear to have a well-marked though porous columella, which, so far as I know, is not characteristic of *Donacosmilia* at any age.

Subfamily Astræinæ.

Tribe Lithophylliaceæ.

Genus Montlivaltia, *Lamx.*

Oppelismilia, Duncan.

It has been quite fully shown by M. Milaschewitsch how much this genus is subject to rejuvenescence, and that under its agency forms appear which at first sight may seem to be quite distinct from *Montlivaltia*. Such, as pointed out by him, is the genus *Oppelismilia*, the brief definition of which, furnished by Prof. Duncan, is that of a *Montlivaltia* with calicular gemmation. The process, however, by which the example which became the type of the genus was produced is quite distinct from gemmation, and the genus thus formed must give way.

I have met with a *Montlivaltia* from the *Trigonia*-grit of Brown's Hill, near Seven Springs, which, while it fulfils the above definition, and really has true calicular gemmation, is nevertheless nothing more than a *Montlivaltia*, and of a species which is by no means uncommon there. But up to this time only one example having gemmation has been met with. In that part of the corallum consistent with the position of the upper margin of the wall is imbedded a young corallite, obviously of the same species as the parent one. It has every appearance of having grown from the top of the wall, and both calices have grown together and have pushed each other out of shape. There is no proof, however, that the young calice was not produced by the accidental growth of an ovum in a part of the calice where it would not at once cause the death of the parent.

Montlivaltia tenuilamellosa, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 130, pl. xxvi. fig. 11 (1851).

As is the case with so many of the *Montlivaltiæ* of the Inferior Oolite of Gloucestershire, the present species is represented by individuals which have a very dwarfed growth.

Compared with the figure given by the original describers, two of the three at present identified specimens do not exhibit more than half, and the third not more than three fourths, of the size of that figure. They all differ also in having a less elongated fossula and more crowded septa. There are from 175 to 180 septa constituting five complete cycles and one incomplete cycle. In all of them the epitheca is lost, and they are much worn.

Two have been collected from the Crickley-Hill reef, and one from the Pisolite at Leckhampton.

Montlivaltia concinna, n. sp.

The corallum is small and pedunculate, and the peduncle is two

thirds of the whole height of the corallum. It is attached by a small base and has an epitheca which is thick but not concentrically wrinkled, and which does not extend to the margin of the calice.

The calice is elongated, one of its sides being nearly straight and vertical, while the other is rounded and bent outwards. It is deep, and although elongated, its fossula is very short, being almost round. The margin of the calice is more or less expanded and everted all round.

The septa are exsert, but they slope inwards and downwards into the centre of the calice without any break or interruption. They are alternately large and small, but all are relatively thick at their outer ends, and decrease in substance evenly as they approach the fossula, where they meet but do not unite. Their margins are all papillated, but not very regularly. There are five cycles and the rudiments of a sixth. Those of the first, second, and third cycles are nearly of a length; those of the fourth are not more than half the length of the former; and those of the fifth are quite short.

Height of the corallum 6 lines.

Greatest diameter of the calice 7 lines.

Shortest diameter of the calice 5 lines.

Three occurrences only of this small coral have come to my knowledge. Two have been collected from the Pisolite at Leckhampton, and one from very near the sands at the base of the Inferior Oolite at Dover's Hill near Chipping Campden.

MONTLIVALTIA MORRISI, Duncan, Supp. Brit. Foss. Cor. pt. iii. p. 17, pl. ii. fig. 13 (1872).

Only one specimen has occurred to my knowledge in the Inferior Oolite of Gloucestershire. It is a dead one and partially obscured by Serpulæ, but agrees pretty closely with Prof. Duncan's description and figure. It has a distinctly peduncular foot, and the septa meet in the centre of the calice in a whorl. It only differs from the type specimen in having the upper part of the corallum non-expanding, but of a cylindrico-ovoid form with an oval calice.

It was found by me in the Crickley reef.

MONTLIVALTIA CUPULIFORMIS, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 132, pl. xxvii. fig. 1 (1851).

A *Montlivaltia* answering well to the figure and description above quoted was taken by me from the compact yellow stone which lies between the Pisolite and the Cephalopoda-bed at Crickley Hill.

MONTLIVALTIA WRIGHTI, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 131, pl. xxvi. fig. 12 (1851).

A single ill-preserved specimen of a *Montlivaltia*, having all the calicular peculiarities mentioned by MM. Edwards and Haime as characteristic of this species, was given to me with a large number of rejected corals from Crickley by Dr. Wright as long ago as 1859, but remained unnoticed until the present time.

The large septa of the fifth cycle are very well shown, passing

inwards and being two thirds of the length of those of the first cycle. The fossula, not visible in the type specimen, is in this one small, round, and well defined. The only real difference between this specimen and the one figured by Edwards and Haime lies in the thickness of the septa generally, those of my specimen being thinner than those in the original one.

Montlivaltia Painswicki, Dunc. Supp. Brit. Foss. Cor. pt. iii. p. 17, pl. i. fig. 12 (1872); Tomes, Geol. Mag. dec. ii. vol. v. 1878.

The use of Prof. Duncan's type specimen of this species, kindly supplied by Dr. Holl, has enabled me to confirm my decision respecting the coral I referred to this species which I obtained from Crickley. It appears to be a well-marked species, and occurs in the lower reef at Crickley and in the middle reef at Painswick.

Montlivaltia trochoides, Edw. and Haime, Ann. des Sci. Nat. sér. 3, vol. x. p. 229 (1848); Brit. Foss. Cor. pt. ii. p. 129, pl. xxvii. figs. 2–4 (1851).

All the specimens of this species which I have seen from the Inferior Oolite of Gloucestershire have been of small size, and very often showed evidence of a dwarfed growth.

Montlivaltia porpita, n. sp.

The corallum is turbinate, short, and attached by a small base.

The epitheca is thin, smooth, and rudimentary, and does not extend quite to the margin of the calice.

The calice is a very little elongated, and the fossula is wide and has a small and slightly elongated centre.

The septa are numerous, thickly set, and somewhat exsert. Their sides are ornamented with vertical ridges which are very strongly marked and terminate in large but very irregular tubercles.

There are five complete cycles of septa and part of a sixth. Those of the first and second meet and blend, but do not form a false columella. They are very thin outwardly, but increase in size regularly as they approach the centre. Those of the third cycle are about two thirds the length of the first and second, and the others decrease in length according to their order.

It is only the longer septa which increase in thickness inwardly, but all have rough tubercles which are sometimes fused together. There are about twenty of these on the longer septa.

Height of the corallum 5 lines.

Diameter of the calice 7 lines.

This species may be very readily distinguished by its peculiar septa, which thicken inwardly, and have very large and ill-defined tubercles. It bears a slight resemblance in this respect to a small species from the Upper Lias of Oxfordshire, which I have described under the name of *M. tuberculata* *.

It occurs in the *Trigonia*-grit at Leckhampton Hill, and at

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 179, pl. ix. fig. 7 (1878).

Ravensgate Hill, but is rare at those places. I have also obtained one from the *Perna*-bed at Cold Comfort, and another from the *Trigonia*-grit between Bourton-on-the-Water and Notgrove station, on the Banbury and Cheltenham railway. In these two examples the septa, while retaining their thickness as they pass inwards, do not actually become thicker in that direction.

MONTLIVALTIA SMITHI, Edw. and Haime.

Only three instances of the occurrence of this coral have come to my knowledge. They were all found in the *Trigonia*-grit, one at Ravensgate Hill, one at Leckhampton Hill, and the other at Brown's Hill near Seven Springs.

It is a Great Oolite species, and probably its earliest appearance is in this, one of the higher beds of the Inferior Oolite.

MONTLIVALTIA LENS, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 133, pl. xxxvi. figs. 7, 8.

I have recently taken this coral from the compact yellow stone below the Pisolite at Crickley, where it was associated with some other *Montlivaltiæ*.

MONTLIVALTIA, sp.

Somewhat resembling *M. lens*, having a wall which does not occupy the whole of the under surface. The calicular surface is much more elevated than in *M. lens*, and has an inflated and bulging appearance. I have received specimens, I believe identical with this, from M. Rigaux of Boulogne, which he obtained from the Great Oolite near that place. It is twice the size of *M. lens*. It occurs in the *Trigonia*-grit of the Ravensgate and Leckhampton Hills*.

MONTLIVALTIA, sp.

A short coral with a very elongated calice, which is occasioned by elongation on one side only. The fossula is very linear, and the septa very stout. The latter are much exsert, but the calice is very deep. Only one specimen has been met with, and it was taken from the Upper Freestone at Leckhampton.

MONTLIVALTIA, sp.

A *Montlivaltia* of small size and turbinate form, which has an oval calice and stout straight septa. From the *Trigonia*-grit of Ravensgate Hill.

MONTLIVALTIA, sp.

Has a turbinate form with a much elongated fossula and very thin wavy septa.

* I have also seen some examples of this species recently taken by Mr. T. J. Slatter, F.G.S., and Mr. E. A. Walford, F.G.S., from the Inferior Oolite at Hotley Hill, about a mile and a half westward of Hook Norton, Oxfordshire, where they were associated with *Trigonia costata*, *T. producta*, *Terebratula simplex*, and *Clausastræa Conybeari*. As long ago as 1868 I met with a solitary example at that place, but did not then recognize it as distinct from *M. lens*.

Several specimens have occurred at Ravensgate Hill in the *Trigonia*-grit.

The above four species are quite distinct from each other, and from all those mentioned in this paper; but they are not in a good state of preservation, and their specific characters cannot be ascertained with sufficient accuracy for determination.

Genus CYATHOPHYLLIA, *de From.*

CYATHOPHYLLIA OOLITICA, Tomes, Geol. Mag. dec. ii. vol. v. July 1878. (Pl. XVIII. fig. 4.)

In my paper on the Crickley corals I described a single worn specimen from that locality under the above name, which had a much depressed turbinate form. Another example, even more worn than the first, has been since met with, which has a much more elevated form, being cylindrico-turbinate. The newer cycles of septa which were observed by me in the former specimen to have considerable irregularity of development, are very distinctly seen in the second one to pass into the older ones as they approach the columella. This peculiarity I can now trace in the original specimen; and it must probably be regarded as of generic significance, for the same may be readily observed in a specimen of *Cyathophyllia* from the Middle Lias of Normandy—the species, indeed, which constitutes the type of the genus*.

But, before the creation of *Cyathophyllia*, Prof. Duncan had defined, under the name of *Antillia* †, a genus which only differed from *Montlivaltia* in having a large columella; and in a subsequent paper ‡ he called attention to the priority of the name given by him, both names being supposed to apply to species having similar generic peculiarities. It is probable, however, that the above indicated septal structure may sufficiently distinguish *Cyathophyllia* from *Antillia*.

CYATHOPHYLLIA, sp.

A species of this genus which is certainly distinct from the foregoing *C. oolitica*, has an elevated turbinate form, a small spongy columella, and septa which are much less crowded and anastomose more freely.

It is much worn, the edges of the septa being all destroyed, and the greater part of the epitheca. Enough, however, of the latter remains to show that it was pretty well developed.

I refrain for the present from giving a description and imposing a name until better-preserved specimens are obtained.

It was taken from the reef at Crickley Hill by myself.

* Fromentel, Pal. Franç. Cor. Terr. Jurass. p. 86, pl. xviii. fig. 1.
† Quart. Journ. Geol. Soc. vol. xx. p. 28 (1864).
‡ Quart. Journ. Geol. Soc. vol. xxix. p. 556 (1873).

Genus Thecosmilia, Edw. and Haime.

Thecosmilia Wrighti, Dunc. Supp. Brit. Foss. Cor. pt. iii. p. 17, pl. v. figs. 1–4 (1872).

I have made diligent search for this species, and have met with a great many fragments, but as yet have not obtained a sufficiently complete specimen to satisfy me respecting its true affinities. In the transverse fractures of some of the pieces, I have seen something very much like a very porous columella. This, with some indications of lateral gemmation, has led me to doubt whether it will not prove to belong to some other genus than *Thecosmilia*. The acquisition of better specimens is necessary before this can be decided, the one I have seen in Dr. Wright's collection not being wholly satisfactory.

Thecosmilia ramosa, d'Orb. Prodr. de Paléont. t. i. p. 292 (1850).

One specimen only has yet been met with, and that was taken from the lower reef at Crickley Hill by my late friend Mr. J. W. Kirshaw, F.G.S.

Genus Confusastræa, d'Orb.

Confusastræa consobrina, Edw. and Haime, sp.

Clausastræa consobrina, Edw. and Haime, Pol. Foss. des Terr. Paléoz. p. 107 (1857); Hist. Nat. Cor. tom. ii. p. 552 (1857); E. de From. Introd. Etude Pol. Foss. p. 281 (1858–61); Tomes, Geol. Mag. vol. v. 1878.

Confusastræa consobrina, Ferry, Mém. Ool. Inf. de Mâcon, p. 23 (1862).

Under the name of *Clausastræa consobrina*, I gave the present species in my list of Crickley corals; but a reexamination of the specimen and comparison with some others from the Inferior Oolite of the Cheltenham district, as well as with two other species from the Great Oolite, has convinced me that it should be removed to the genus *Confusastræa*. This has, indeed, been done by M. Ferry as long ago as 1862; but his paper was overlooked by me when I was before working out the Crickley corals.

There are three characters in this species which deserve especial mention, because they are most likely generic. One of them is the existence of very distinct walls between the corallites, as in *Isastræa*, which are not visible until the calices are worn down; another is the presence, deep in the calice, of a pimple-shaped columella; and the third consists of very distinct mural costæ, which are spread over the whole of the under surface of the basal plate and arranged in fasciæ. If there is an epitheca on the common basal wall or plate, it has been lost in all the specimens I have seen. The genus *Adelastræa* of Reuss, from the Cretaceous beds of Gosau, is founded upon a species of *Confusastræa*.

I have obtained this species from the lower reef at Crickley and from the middle reef at Leckhampton.

CONFUSASTRÆA TENUISTRIATA, n. sp. (Pl. XVIII. fig. 11.)

The supposition expressed by me that the *Isastræa tenuistriata* was not a true *Isastræa* has had partial confirmation by the examination of a considerable number of specimens, which show that two species have been confounded under that name.

The original description by M'Coy, as well as that afterwards given by MM. Edwards and Haime, will apply to one of these, which is a true *Isastræa*, though probably not a very typical species.

The other is a species of *Confusastræa*, and may be described as follows:—

The corallum is depressed and of a rounded or ovoid form. The under surface is a little convex, and is enclosed in a common wall and epitheca, notwithstanding which, however, the outline of each corallite, both inferiorly and laterally, is well defined. Laterally they are so distinct that they give to the corallum the appearance of a bundle of short sticks in close approximation, and there is no appearance of any ramification of the corallites by either lateral gemmation or fissiparity.

The calices are either round or oval, or, when pressed together, lozenge-shaped. They are concave, with a small, ovoid, deep, and well-defined fossula, and the septa are exsert only near the outside of the calice. Between the calices is a very distinct though narrow line of depression.

The septa are thin, and less closely placed than in *Isastræa tenuistriata*, the interceptal loculi being of a breadth quite equal to three times that of the septa. The number of septa in a well-developed calice is nearly ninety; that is, there are four complete cycles, and a fifth which is not complete. The septa forming the first, second, and third cycles extend to the centre, and pass into the fossula; those of the fourth are half the length of the others, and those of the fifth are rudimentary. All are evenly and delicately but very distinctly geniculated.

Some of the outer and half-enclosed corallites have a peculiarity which is deserving of notice, and which I have observed in some of the Liassic *Isastrææ*, though I have not before seen it in any of the massive Oolitic Astræidæ. I refer to the apparently intermittent growth of the individual corallites, which have somewhat the appearance of those of some of the Rugosa. They do not, however, possess a true Rugose character, though they probably approximate the species to the Triassic genus *Elysastræa* of Laube *, from which, however, it differs in having a well-developed epitheca, and gemmation which is confined to the circumference of the corallum †.

The inner ring of septa in *Elysastræa*, as shown in Laube's figure and in the figures given by Prof. Duncan ‡, appears to me to be due only to this *rejuvenescence* of the corallites. It is merely a new calice arising from the centre of an older and larger one, just as we

* Die Fauna der Schichten von St. Cassian, p. 261, pl. v. fig. 6 (1864).

† Indicating, perhaps, some affinity with the group containing *Latimæandra*, *Chorisastræa*, and *Phyllogyra*.

‡ Supp. Brit. Foss. Cor.

so often see is the case in simple Astræidæ, though it is much more rarely observed in the compound species. I have now before me a specimen of *Isastræa Murchisoni*, from the Lias of Skye, in which the inner calice is very distinct in some of the larger and older calices, just as in *Elysastræa*, to which genus this species is closely affined.

A reference to the figures of *Isastræa tenuistriata* lately published by Prof. Quenstedt* may be desirable, as they explain in some degree the peculiarities I have mentioned, though at the same time they seem to indicate intercalicular gemmation. That celebrated palæontologist does not, however, appear to have regarded the species as possessing affinity with *Elysastræa*, but, associating it with *Isastræa helianthoides* and *Isastræa explanata*, considers them as the ultimate development of the form which he distinguishes by the name of *Cœnotheca*. The last-named genus is almost unknown in this country; and I am unable to offer any opinion on the relationship here suggested between it and *Isastræa*, excepting to remark that both increase by gemmation and not by fissiparity.

I have placed this curious species in the genus *Confusastræa* with considerable doubt, because it possesses some peculiarities which I have not seen in that genus, though it is quite possible that they exist. One of these is the mode of gemmation, which is wholly external, and takes place so low down on the outside of the corallum that none of the corallites can properly be said to be furcate. Another is the great distinctness of the corallites, notwithstanding that they are enclosed by a common and thick epitheca; and another the distinct periods of renewed growth or rejuvenescence.

It has only as yet been found in the lower reef at Crickley Hill.

Tribe Astræaceæ.

Provisionally I regard the genera which appear in the following Table as referable to the tribe Astræaceæ, at the same time, however, pointing out that M. de Fromentel has elevated two of them to the rank of a family. These are *Latimæandra* and *Chorisastræa*.

I have included *Isastræa* in the classification, although it has not serial calices, to show how near *Latimæandra* comes to it in having some of the calices single. But the similarity to it in that respect must not be regarded as of much importance, because gemmation may at any time take place in the simple calices, and they may become serial, and remain characteristically representative of the genus *Latimæandra* by remaining in a series.

Of all the species of *Latimæandra* which I have examined, *L. Davidsoni* and *L. Flemingi* have the most regularly developed inner walls, and approach most nearly to the genus *Isastræa*. In these species, when gemmation takes place, as it does, within the calice, a distinct wall often appears after a time around the young corallum, as in *Isastræa*. This does not happen in the allied genus

* Petrefact. Deutschl., Korallen.

Phyllogyra, in which no inner wall is produced. I think it is very probable that some of the recorded species of *Latimæandra* will have to be removed to this genus, and only such species as have distinct inner walls, produced quite independently of the outer or enclosing ones, included in the genus *Latimæandra*.

ASTRÆACEÆ.

Astræidæ having both simple and serial calices, and increasing by gemmation. The corallum
- massive. The corallites divided into series, or single ones, by true walls. Gemmation calicular. The calices
  - simple .... *Isastræa.*
  - both simple and in series .... *Latimæandra.*
- massive, subdendroid or depressed. The corallites not divided by walls. Gemmation
  - basal. The corallum lobular, the lobes springing
    - from the base of parent corallite. *Chorisastræa.*
    - from the bases of secondary corallites, as well as from the parent. *Heterogyra.*
  - Calicular or septo-costal. The corallum
    - turbinate......... *Cœnotheca ?*
    - composed of leaf-like expansions. *Phyllogyra.*

Genus ISASTRÆA, Edw. and Haime.

ISASTRÆA SERIALIS, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 16, pl. xxiv. figs. 2–8 (1851).

I have already, in a paper on Oxfordshire Oolitic Corals *, given this as an Inferior-Oolite species, and now, on the evidence of two specimens, add it to the list of Gloucestershire species. One of them is in the collection of Dr. Wright, and the other in my own. The latter was taken by me from the débris in a cavity in the compact yellow stone under the Pisolite at Crickley.

ISASTRÆA TENUISTRIATA, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 128, pl. xxx. fig. 1, not Tomes, Geol. Mag. vol. v. 1878.

Astræa tenuistriata, M'Coy, Ann. & Mag. Nat. Hist. ser. 2, vol. ii. p. 400 (1848).

The examples of this species which I examined before writing my paper on "The Crickley Hill Corals," were, there is no longer any doubt, referable to another genus, and are now described as a *Confusastræa*. But other specimens have occurred which are undoubtedly referable to M'Coy's *Astræa tenuistriata*. In his description he says, "centre obscurely granular;" and in some specimens from the *Trigonia*-grit at Ravensgate Hill I have observed this peculiarity sufficiently pronounced to almost assume the appearance of a papillose columella. I have not hesitated, therefore, to reform

* Proceed. Geol. Assoc. vol. vi.

the synonymy as above; but there are other respects in which the present species differs from the species of *Confusastræa* which is now also named *tenuistriata*. The septa are much more closely placed; and occasionally those of the newer run into the older ones. Besides this, there is a common basal wall, of an expanded turbinate form, which has the costæ considerably exposed, and is encircled by narrow rings of epitheca; gemmation is pretty frequent, and takes place from the walls, in the angles where they meet those of other calices.

The most typical examples have been procured from the *Trigonia*-grit at Ravensgate Hill and Birdlip Hill: and, so far as I am aware, it does not occur in either of the other zones of the Gloucestershire Oolite.

Isastræa depressa, Tomes.

Isastræa expansa, Tomes, Geol. Mag. vol. v. 1878.

Since the appearance of my former paper, I have learned that the name I had given to this species was already made use of; and I now therefore substitute the above.

This is a common species in the lower reefs at Crickley and the Horse Pools: but, owing to its thinness, it is seldom met with except in fragments. It is desirable to state that subsequent research has led me to suspect that this species is by no means typical of the genus *Isastræa*. The continuity of the septa over the thick walls, as in the *Isastræa foliacea* of M. de Fromentel, from the Portland Oolite of France, is very suggestive of septal costæ and an exotheca, the existence of which would remove this species from the present genus. At present, however, I have failed to discover either exotheca, dissepiments, or synapticulæ.

Genus Latimæandra, d'Orb.

Latimæandra Flemingi, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 136, pl. xxvii. fig. 9.

This is a common species at Crickley Hill, but it is almost always crystalline inside, and sometimes is nothing more than a hollow cast. This I have repeatedly observed, whilst *Thamnastrææ* taken almost in contact with it usually have the internal parts well preserved.

Latimæandra Davidsoni, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 137, pl. xxxvii. fig. 10.

Occurs in the lower reef at Crickley Hill.

Latimæandra Haimei, n. sp. (Pl. XVIII. fig. 15.)

The corallum has an irregular expanded form, and is wider than high. The under surface exhibits a broad peduncle, overhung by the upper part, which is somewhat fungiform with a convex upper surface.

The under part is rugged and wholly without epitheca; the mural

costæ are equal and of about the same thickness as the septa; and the spaces between them are a little wider than the costæ themselves.

The series of calices are generally straight, and the greatest number in one series is three. The walls are rather prominent, but are completely hidden by the septa, which come into contact with those of adjoining calices on their summits. The calices are shallow, but very well defined, the single ones being saucer-shaped and having no fossula. In some of them the bottom is nearly flat and of nearly the full breadth of the calice.

The septa are nowhere exsert, their upper margin forming a gentle concave line which, when unworn, has about ten well-formed papillæ; when these are worn off, the septa have a very uniform and smooth appearance. There are three cycles, and part of a fourth. The septa of the first and second cycles are of equal thickness throughout, and meet and blend in the centre of the calice, but without forming a false columella; those of the third cycle are three fourths of the length of those of the first and second; and those of the fourth vary according to their degree of development, but in some of the systems they are about half the length of those of the first and second cycles.

The dissepiments are abundant.

The diameter of the furrows is about 2 lines The height of the corallum is $1\frac{1}{2}$ inch, and its diameter $2\frac{1}{2}$ inches.

I have only met with one specimen of this species; and it was obtained from the oolite marl at Sheepscombe, by Mr. W. Jenkins of Cheltenham.

There is no difficulty in distinguishing this species from the other English ones. The shape of the calices, the uniformity in the thickness of the septa, and their union with each other in the centre of the calice will easily distinguish it from *L. Davidsoni*; and with the large-caliced *L. Flemengi* it cannot for a moment be confounded. Moreover the septa of the latter species often anastomose, which they never do in the present species.

LATIMÆANDRA TABULATA, n. sp.

The corallum is massive, and the corallites, though well defined and appearing in *bas relief* on the lower and outer parts of the corallum, are attached to each other and have a common epitheca.

In shape the corallum is subcylindrical, and as high as wide. It is attached by a small base, from which the corallites spring and radiate almost horizontally until they have formed the base of the corallum of the full diameter to which the corallum attains. Then another tier is placed upon them, and so on until the height of the corallum is attained. The exposed or outer boundary of these tiers of corallites consists of calices which are sometimes surrounded by a narrow ring of epitheca, though more frequently a bundle instead of a single one is so surrounded.

Each corallite has rather numerous accretion-ridges; and there is an increase in their diameter at these points.

The epitheca is well developed, and presents numerous rings and folds.

On the top of the corallum the calices are crowded and have more or less of an angular outline, as in *Isastræa*; but in well-preserved calices the septa are all exsert, and a narrow furrow invariably indicates their line of contact with each other. In younger specimens they are less closely packed; and then they preserve their rounded form.

When rubbed down, the corallites are seen to be distinct from each other, though there is not space enough between them for the growth of any exotheca.

The septa are rather thick, exsert, and have their margins furnished with regular tubercles, of which there are eight or nine on each septum.

There are five cycles and part of a sixth. The primary ones are all of nearly uniform thickness, and almost meet in the centre, leaving a very small and irregular fossula. The septa of the second cycle are nearly as long as the first, and those of the third are two thirds of the length of the first.

Diameter of the corallites about 2 lines.

Height of the corallum 6 inches, diameter 4 inches.

From the oolite marl at Sheepscombe. Young examples have also been taken from the same bed by my friend Mr. T. J. Slatter, F. G. S., and by myself at Leckhampton Hill.

Genus Chorisastræa, *de From.*

Chorisastræa rugosa, n.sp.

The corallum springs from a point of attachment, and is at first massive; but the corallites are afterwards divided into groups or are single.

The under surface is rugged, and expands upwards and outwards, and the corallites show in *bas relief*.

A common, wrinkled and thick epitheca encloses the under part as well as the bundles of corallites and the single ones. The upper or calicular surface is flat, and the calices are arranged a good deal in series. Towards the centre the calices are most crowded, and constitute oftentimes a confused mass of confluent calices; but towards the outside, and even when not divided either into single calices or into groups, they are well defined, round and prominent, and sometimes have a rudiment of epitheca surrounding them. Their septa are exsert, rather stout, and diminish in thickness as they approach the centre of the calice, where the greater part of them unite and form a spurious but dense columella.

It is rather difficult to determine with exactness the number of cycles; but in the single and prominent calices there are about 120 septa, or five cycles and part of a sixth.

All the specimens examined have lost the edges of the septa; but the vertical ridges which ornament their sides remain and are acute, irregular, and not very near together.

Dessepiments are abundant.

I have met with this species in the lower reef only, at Crickley Hill,

and at the Horse Pools, near Gloucester, at which places it is not uncommon.

Chorisastræa gregaria, M'Coy, sp. (Pl. XVIII. figs. 1–3.)

Montlivaltia gregaria, M'Coy. Ann. & Mag. N. H. ser. 2, vol. ii. p. 19 (1848).

Thecosmilia gregaria, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 135, pl. xxviii.

MM. Edwards and Haime, in their great work on the British Fossil Corals, after stating that the corresponding calices in *Thecosmilia annularis* are on the same level, observe that that peculiarity is, however, only attained with age, and that therefore specimens of various ages are necessary for the purpose of investigation*.

Of *Thecosmilia trichotoma* they say that the corallites "arrange themselves so as to constitute a short row, and do not separate immediately from each other; it may even happen that a few of these small series of corallites remain in contact laterally, and thus assume the form of *Symphyllia*. But these variations in the general form are only met with in young specimens, and have never been met with in the older large corals"†.

The same authorities speak of *Thecosmilia gregaria* as follows:—"*T. gregaria* differs still more from the preceding species [*Thecosmilia annularis*] by the corallites remaining in general grouped in fasciculi to a considerable distance from the parent calice on which they were formed by fissiparous gemmation, a mode of arrangement which we have not met with in the other corals of the same genus"‡.

From the foregoing passages it is evident that even so long ago as 1857 the present species was not regarded as typical of the genus: and Prof. Duncan, in his Supplement to the work of MM. Edwards and Haime, appears to have found even greater difficulty in defining the species with precision; for he speaks of as many as five varieties from Crickley alone, which, excepting for the examination of a considerable series from other scources, might have been supposed to have relations with *Heterogyra*, *Symphyllia*, and *Latimæandra*. Prof. Duncan also refers to a series in Dr. Wright's collection which appear to graduate into *Symphyllia*§.

In my former paper on Crickley corals I expressed an opinion that, with the examination of a greater number of specimens of this species and of more varied age, a different and more definite conclusion respecting its affinities would be arrived at; and I held that opinion because I had already seen some young individuals which only required identification with *Thecosmilia gregaria* to furnish characters which would remove it from the genus *Thecosmilia* altogether. The acquisition of a great many specimens of all ages has supplied the intermediate forms; and these have led to the appearance of this well-known species with those with which it is here associated.

In young and typical individuals the appearance is that of a much

* Page 84. † Page 85. ‡ Page 87.
§ Supp. Brit. Foss. Corals.

depressed *Montlivaltia*, attached by its whole breadth; and the first indication of a deviation from that form appears by the outer margin assuming greater lateral prominence, and becoming somewhat lobate. With continued growth the lobes become more distinct, until their sides meet and push each other upwards into short subcristiform ridges. About this time gemmation first makes its appearance amongst the elongated septa (costæ) near the extremity of the lobes, sometimes in each one simultaneously, and producing a complete circle of young calices around the parent one; though more frequently they are few in number, and irregular both as to position and time of making their appearance.

Although I have examined great numbers of this coral, I have hitherto wholly failed to detect gemmation taking place after the formation of the basal portion of the corallum; and if it is confined to that part, this species would resemble *Chorisastræa* in its mode of development.

The corallites which have more than one calice, have often much the appearance of fissiparous growth; but a close examination shows that the calices are the result of gemmation which took place lower down in the corallum, and that they have continued their near relationship to each other while the coral was increasing in height. This I have ascertained by means of sections, showing that very frequently two or more calices hold precisely the same position in relation to each other on the summit of a corallite that they did near to its junction with the peduncle from which it and other corallites sprung.

I have arrived at the conclusion that the serial arrangements of the calices in the group to which this species belongs, must be regarded as an ultimate and essential character, and not as representing fissiparity in the process of dividing the calices into series, to be again brought into corallites with simple calices by the mere process of upward growth.

Phyllogyra, n. g.

The corallum has a more or less depressed and massive form, and is composed of a series of leaf-like expansions, proceeding laterally from a parent corallite, the curled-up margins of which unite and form sinuous cristiform ridges, the line of union of which is very distinct in the younger examples, but much less so in the older ones.

Gemmations take place successively amongst the elongated septa (which must be regarded as costæ rather than septa), and generally towards the extremity of the leaf, and a more or less distinct line of calices is produced.

There appears to be no intercalicular gemmation, so common in many of the Astræidæ, as, for instance, in *Isastræa* or even in *Latimæandra*; and when lateral gemmation has ceased, the corallum only increases in height by the growth of the single or serial corallites upwards.

There is a common or basal wall, which is either naked or costulate, or has bands of rudimentary epitheca. It is by the folding

inwards of this outer wall, and not by the growth of inner walls, as in *Isastræa* and *Latimæandra*, that the sinuous ridges are formed.

It is with *Latimæandra* rather than with *Heterogyra* that this genus is by its mode of gemmation most nearly associated; but there are no true walls as in *Latimæandra* either dividing the calices into short series or enclosing single ones. Moreover the elongated septa of *Phyllogyra* are true costæ; and none such occur within the well-developed walls of *Latimæandra*.

Phyllogyra Etheridgei, Dunc. sp.

Symphyllia Etheridgei, Duncan, Suppl. Brit. Foss. Cor. pt. iii. p. 19, pl. vi. figs. 5–8.

This species has been met with quite commonly in the *Trigonia*-grit at Leckhampton; and I have a single specimen which was obtained somewhere near Cooper's Hill by my late friend Mr. J. W. Kirshaw, F.G.S.; but from no other locality have I as yet met with it. It appears to be wholly confined to the upper reef of Dr. Wright; and the Leckhampton specimens occur, for the most part, quite at the bottom of the bed which takes its name from the *Trigonia costata*.

A specimen in Dr. Wright's collection has been named by Prof. Duncan; and an examination of it, with the opportunity of comparing numerous and more characteristic specimens, has enabled me to determine its true character with tolerable certainty. The Cooper's-hill example shows gemmation actively taking place at the margin of the leaf-like expansion.

Phyllogyra sinuosa, n. sp. (Pl. XVIII. figs. 5–7.)

The corallum is of rather small size and depressed, the under surface being either flattened or concave; and there is no appearance of a peduncle. The upper surface is either flat or convex.

The furrows are sometimes long and rather deep, and they are nearly as wide at the bottom as at the top. They are very tortuous, of very unequal breadth; and the ridges bounding them are consequently very sinuous. These furrows, with their surrounding ridges, are in fact long unsymmetrical leaves, often having lobes, the edges of which are turned up all round and rise up into a kind of peak, where they meet and make angles. At no point do these ridges present the appearance of true walls, as in *Latimæandra Davidsoni* and *L. Flemingi*. Not more than six calices occur in one leaf or furrow. They are small, rather deep, pretty well defined, and not very closely placed.

The septa are thin, flexuous, equal in thickness throughout; and the principal ones pass quite into the centre of the fossula, but do not there form a mass. Their edges are delicately papillated. They frequently anastomose, but only near the outside of the leaf, where they must be regarded as septal costæ rather than as septa. There are about twenty-four septa to each calice.

Gemmation takes place near to the margin of the leaf, and more frequently on the side of the corallum than on the top—that is

to say, more frequently at the ends of the leaves than at their curled-up lateral edges, thus promoting an outward or horizonal, rather than an upward or vertical growth.

The largest corallum observed has a diameter of 3 inches, and a height of 1 inch.

The longest leaf or furrow, following its curves, is 1 inch, and its diameter $1\frac{1}{2}$ to 3 lines.

I have taken examples of this coral from the oolite marl of Leckhampton Hill; and one has been forwarded to me from Mr. W. Jenkins, of Cheltenham, which he took from "the oyster-bed," Cleeve Hill.

Genus Cœnotheca, Quenst.

This genus has been proposed by Prof. Quenstedt for a small group of the Astræidæ, which while retaining the form of simple turbinate *Montlivaltiæ*, nevertheless have some smaller calices placed in an irregular manner outside a larger and more central one.

The definition of the genus is unsatisfactory, and, without the excellent figures which accompany it, would be of very little value.

So far as I can judge, the smaller calices are the result of gemmation, and not of fissiparity; and I believe the genus, if a good one, should be placed in connexion with *Latimæandra*, *Chorisastræa*, and *Phyllogyra* (see p. 448).

I have met with a specimen from the Pisolite of Crickley Hill, which seems to fulfil the conditions necessary for its identification with this genus; but I have regarded it hitherto as the peduncle of some species.

Genus Goniocora, Edw. & Haime.

Goniocora concinna, n. sp. (Pl. XVIII. figs. 18, 19.)

Fragments in a pretty good state of preservation of a small species of coral referable to this genus are not uncommon in the lower reef at Crickley Hill; they are quite distinct from those of the Coral Rag of England, France, and Germany.

The species to which it bears the greatest resemblance in size, mode of growth and number of septa, is the one figured by M. de Fromentel under the name of *G. Haimei*; but it differs from this considerably in the number of cycles of the septa, and in the relatively greater development of the higher orders.

It appertains to the "décaméral" division of the genus, and cannot be confounded for a moment with our Steeple-Ashton species, which has the normal number of septa, six, instead of, as in this species, ten primary ones.

It is a small species; and the mural costæ are nearly smooth, and have between them rather scattered dissepiments. On some of the branches are intermittent rings of rudimentary epitheca.

The septa are somewhat exsert, and have regular papillated margins, the number of papillæ being about ten or twelve. They are much less stout at the outer end than in either *G. Haimei* or *G.*

socialis; and consequently they do not decrease in size so rapidly as they approach the centre of the calice.

There are ten primary septa, and an equal number of secondary ones, which are two thirds the length of the primaries. The tertiary septa, completing the septal formula, are half the length of the secondary ones.

In sections of the corallites an elongated columella is visible; but this cannot be seen in the unworn calices.

I have not, up to this time, met with any other representatives of the genus in the Inferior Oolite except the present one, and I have only obtained it from Crickley Hill.

Family *FUNGIDÆ*.

Genus Thecoseris, de From.

Thecoseris polymorpha, Tomes, Geol. Mag. Decade ii. vol. v. 1878. (Pl. XVIII. figs. 12, 13.)

Since the description of this species appeared several other examples have been met with, some of which, obviously younger individuals, differ from those described in being attached. Probably with greater age they would become free.

On this genus* I made some observations, comparing it with *Turbinoseris* and *Podoseris*†, which now require modification. The latter genus was formed for the reception of two species from the Red Chalk of Hunstanton. After the description of the genus, Prof. Duncan states that "the genus has been created to admit *Micrabaciæ* with adherent bases and more or less of a peduncle." Recent researches, however, made with the assistance of specimens in better preservation, have brought to light some quite unexpected features which will remove these Cretaceous species from the genus created for them, and place them in an old and well-defined one. When these are eliminated the genus *Podoseris* will rest solely on the *P. constricta* of the Inferior Oolite of Dorset, which differs from the species forming the type of the genus, in having a restricted instead of an expanded base, and in being destitute of epitheca. This approximates it more nearly to *Turbinoseris*, which may have either an expanded or contracted base, and may have an epitheca which is rudimentary, but which is frequently distinct‡. How nearly the genus *Turbinoseris*, as amended by Prof. Duncan, may resemble *Thecoseris* I am not fully prepared to say; but it would seem that the latter is much more nearly allied to the more recently created genus *Palæoseris*§. With this genus it will, according to my view, be found to be identical.

The present species has been met with in the lower reef at Crickley, the Horse Pools near Gloucester, and near Cooper's Hill.

* From. et Ferry, Pal. Franç. Terr. Jurass. pl. lviii. fig. 2, 1869.
† Duncan, Supp. Brit. Foss. Cor. pl. ii. p. 25, 1869.
‡ Duncan, Quart. Journ. Geol. Soc. vol. xxix. p. 558.
§ Ibid. vol. xxvi. p. 301.

ZOANTHARIA PERFORATA.

Family *PORITIDÆ.*

Subfamily Poritinæ.

Genus Anabacia, d'Orb.

Anabacia complanata, M.-Edwards, Hist. Nat. Cor. tom. iii. p. 31.

Fungia complanata, Defr. Dict. Sc. Nat. tom. xviii. p. 27 (1820).

Anabacia orbulites, Edw. & Haime, Brit. Foss. Cor. pt. ii. p. 120, pl. xxix. fig. 3.

M. Edwards has, in the third volume of the 'General History of Corals,' referred this very common species, and no doubt correctly, to the *Fungia complanata* of Defrance.

Its place as a lower-reef species rests upon a single specimen obtained at Crickley by Mr. W. Jenkins, of Cheltenham. I have one from the oolite marl at Leckhampton Hill (which is the middle-reef), and a considerable number from the Lower *Trigonia*-grit (or upper reef) of Leckhampton Hill, Ravensgate Hill, Brown's Hill, near Seven-springs, and from the railway-cutting between Bourton-on-the-Water and Notgrove, on the Banbury and Cheltenham railway.

Genus Thamnastræa, Le Sauvage, 1822.

The removal of this genus first from the Astræidæ to the Fungidæ, and afterwards to the Poritidæ, has resulted from the substitution of the investigation of internal structure for the mere examination of outward form; and it yet remains to submit all the species at present included in the genus to that strict method of inquiry. After the careful examination of a great many specimens of *Thamnastræa arachnoides* from Steeple Ashton, I have failed to ascertain whether the septa are perforate or not. If the septa of that species should prove to be imperforate, as I believe they will, it would have to be put back to its place in the Fungidæ, and probably all the other species which have been placed with it in the subgenus *Synastræa*.

Two species of this group I have described from the Middle Lias of Oxfordshire, under the names of *T. Etheridgei* and *T. Walfordi*. The *T. Manseli* of Prof. Duncan is another species; and two others are here described as *T. crickleyensis* and *T. Duncani*. Probably *Thamnastræa Dumonti* of MM. Chapuis and Dewalque*, as well as the *T. papillosa* and *T. biformis* of Reuss†, are referable to this subgenus.

The genus *Astræomorpha*, proposed by Reuss in 1854 ‡, has been subjected, at the hands of Milaschewitsch §, to the same critical exa-

* Foss. Terr. Sec. de Luxemb. p. 270, pl. xxxviii. fig. 11.

† Denkschr. der Akad. Wissensch. Wien, 1867.

‡ "Beitr. zur Char. Kreide. Ostalpen.," Denkschr. der Akad. Wiss. Wien, 1854, p. 127, pl. xvi.

§ Palæontographica, vol. xxi. p. 222.

mination which has been exercised on the allied genera *Thamnastræa* and *Microsolena*; and the result has been its establishment as a subgenus.

There seems no doubt that it corresponds with the subgenus *Centrastræa*, proposed by de Fromentel in 1858–61*; and therefore, while we adopt the name of *Synastræa*, proposed by de Fromentel, for such *Thamnastrææ* as have a spongy columella, we must also make use of the name of *Astræomorpha*, given by Reuss to those which are characterized by the existence of a styliform columella.

The true *Thamnastrææ* would then be those which have no columella.

Subgenus Synastræa, de From.

Thamnastræa (Synastræa) crickleyensis, n. sp.

The corallum has a depressed form, the under surface being a little convex, with a subcentral prominent part, which was a point of attachment. The upper surface is flat, and presents an oblong figure, which is somewhat kidney-shaped, with the outer edge thin and a little undulating.

The epitheca is rudimentary and disposed in rings; but as there is much more of it on one side of the corallum than the other, it is probable that it has been equally developed, but since destroyed.

The mural costæ are thin, straight, uniform, and parallel. Their thickness is not more than half the width of the interval between them. Their synapticulæ are distinct, though not strongly developed.

The calices are evenly scattered over the upper surface. They are rounded, with a distinct disposition towards a quadrangular form; and the costæ between them form ridges, which give to the calices much the appearance of those of the *Isastrææ*. The distance from centre to centre of the calices is from 2 to $2\frac{1}{2}$ lines.

The septa and septal costæ are thick; and the latter are almost in contact with each other laterally, where they join those of other calices, with which they form a more or less obtuse angle. They decrease in thickness inwards as they approach the columella, into which they blend. The point at which the septa pass into and become septal costæ is often indicated by the latter becoming forked. All these have lost their upper margins and become smooth. From twelve to sixteen septa occur in each calice, being two cycles and the rudiments of a third.

The columella, when the calices are not much worn, is small, but well defined, and consists of a number of papillæ, varying from three or four to seven or eight. When the calices are much worn down it is of greater size, and presents the appearance of a spongy mass.

This new species has been met with once at Crickley Hill. The specimen was a dead one, with all the calicular surface more or less worn down and partially obscured by a growth of delicate Bryozoa before fossilization took place.

It is to *Thamnastræa arachnoides* of the Coral Rag that the

* Introd. Etude Polyp. Foss. p. 215 (1858–61).

present species bears the nearest resemblance; but it differs therefrom in having the calices nearer together and smaller, and in having the mural costæ much more delicate, further apart, and their synapticulæ more uniform. In *T. arachnoides* these costæ are continuous with the septa, and of the same thickness where they pass over the edge of the corallum; but in *T. crickleyensis* they are not half the thickness of the septa.

THAMNASTRÆA (SYNASTRÆA) DUNCANI, n. sp.

This is a small and turbinate species, which bears a little resemblance to the *Thamnastræa Dumonti* of MM. Chapuis and Dewalque*, but differs from it in having the calices further apart, and in having thin flexuous septal costæ, which anastomose exceedingly. To *Thamnastræa Manseli* it also bears a little resemblance, but differs essentially in having a large spongy columella, and furcate and bifurcate septal costæ, and in having smaller calices and thinner septa.

The corallum is somewhat turbinate, and was attached by a small space. It exhibits periods of growth, and has the outer margin of the calicular surface a little everted.

The epitheca is thick and rather rugose, but of intermittent growth, showing itself as irregular rings around the corallum.

The mural costæ are straight, thin, and appear to be wholly without synapticulæ.

The calicular surface is rather convex; and the calices are scattered over it without order, and are rather far apart in relation to their size.

They are small, round, shallow, and have a spongy columella, which is nearly half their own breadth.

The septa are thin, flexuous, and join the columella. Their margins are irregularly papillated.

The septal costæ are long, flexuous, and anastomose a good deal. They have a radiate arrangement without any tendency to the parallel disposition observable in so many *Thamnastrææ*. Their margins have regular papilllæ. Where they join those from other calices they are very crooked. They have numerous but small synapticulæ, which are not cuneiform and do not approach very near to the columella.

There are two complete cycles of septa and part of a third.

The calices are about 1 line in diameter, and 2 lines from centre to centre.

The height of the corallum is 1 inch, and its diameter $1\frac{1}{4}$ inch.

I have met with only one specimen of this coral; and that was taken by Mr. W. Jenkins, of Cheltenham, from the lower reef at Crickley Hill.

THAMNASTRÆA (SYNASTRÆA) MANSELI, Duncan, Supp. Brit. Foss. Cor. pt. iii. p. 20, pl. iv. figs. 11–14 (1872).

Of this well-marked species I have as yet only seen one speci-

* Foss. Ter. Sec. de Luxemb. p. 270, pl. xxxviii. fig. 11.

men. It was taken by me from the *Trigonia*-grit at Ravensgate Hill. The only difference between it and the specimen which supplied Prof. Duncan's figure is in the septa and septal costæ, which are more uniform in thickness in my specimen than they are shown to be in the figure. That difference, however, is most likely due to those parts having been less worn down in the one from Ravensgate than in the type specimen.

THAMNASTRÆA LYELLI, Edw. & Haime, Brit. Foss. Cor. pt. ii. p. 118, pl. xxi. fig. 4. 1851.

MM. Edwards and Haime mention a cast found near Bath by Mr. Bowerbank which they refer to this species, but observe that the calices are smaller and more crowded than in the specimens from Stonesfield.

Compared with Stonesfield examples, I find that the Gloucestershire ones present precisely the same differences which are here mentioned. But they also have the septa and septal costæ more exsert, becoming on the smaller branches subcristiform, with their papillæ placed transversely. The cycles of the septa are just as in the typical *Thamnastræa Lyelli*.

I do not think the differences here indicated sufficient to constitute a new species.

The basal portion of a specimen from Crickley Hill, showing the attachment, measures $1\frac{1}{2}$ inch in diameter. Fragments of all sizes are to be met with both at Crickley Hill, in the lower reef, and at Leckhampton Hill, in the middle reef.

I have entertained some doubt about the real affinities of this species, and am by no means satisfied that it is really a *Thamnastræa*. In some examples, whether from the Inferior Oolite or the Great Oolite of Stonesfield, from which place the type specimens were taken, there is often an indication of a circular calice, which was hidden until the costæ were worn away. At no age nor in any state of preservation have I succeeded in detecting synapticulæ. If it is one of the Astræidæ, it is to the genus *Convexastræa* that it is most nearly allied, though it possesses a columella.

THAMNASTRÆA WRIGHTI, n. sp. (Pl. XVIII. fig. 14.)

The corallum is oblong or rounded, always more or less depressed, and has the calicular surface varying from a slight degree of concavity to a flat or slightly convex surface. Generally the under surface has a little convexity, with a central prominent point of attachment; but it is sometimes flat, or even concave, with the same prominent part. In one instance only have I seen it with a height greater than the base, formed by layer upon layer.

The epitheca is generally rudimentary, seldom appearing as more than a succession of concentric bands, and it is often absent altogether.

The mural costæ are distinct, straight, delicate, and connected by numerous oblique synapticulæ.

The calices are small, and scattered without order over the upper

surface; but towards the outside there is often a disposition towards a linear arrangement, the lines corresponding with the outer margin. They are distant from each other in every direction about $1\frac{1}{2}$ line.

The septa and septal costæ are thin, and they are irregular both in their length and degree of prominence. They are crooked, but not by a curvature, but by having from two to four angles between one calice and another. The principal ones are much more prominent than the others; but their degree of projection is irregular. All, when unworn, have thin edges, which have rather obscure processes, which are long in the direction of the length of the septum. There is a slight tendency in the septal costæ towards a radiate arrangement: but this is very little observable in many specimens. They very rarely anastomose with each other.

The greater prominence of the principal septa and septal costæ, their thinness when unworn, as well as their angular but not curved form, will distinguish this species from others from the Inferior Oolite.

When worn down the septal costæ have great irregularity, each in its own length: but they do not much differ from each other. The largest specimen I have seen is 5 inches in diameter, and $1\frac{3}{4}$ inch thick.

It occurs plentifully in the *Trigonia*-grit of Ravensgate Hill, Brown's Hill, Birdlip-Hill, and a railway-cutting between Bourton-on-the-Water and Notgrove, and also in the *Perna*-bed at Cold Comfort, near Cheltenham.

THAMNASTRÆA FLABELLIFORMIS, n. sp.

Three instances only of the occurrence of this species, which is distinct from all others I have seen, are known to me.

The corallum of one of the specimens is attached, and consists of three upright turbinate parts, united into a series, and forming a flabelliform figure, surrounded by a common epitheca, and having a flattened top, which constitutes the calicular surface. This is concave across its narrow diameter, and convex along its long diameter.

The epitheca is thick, not very rugose, and has shallow concentric markings. It extends up to the edge of the calicular surface.

Towards the foot of the corallum the mural costæ are partially exposed, and are numerous, delicate, straight, and have thickly set delicate cuneiform synapticulæ.

The calicular surface has an irregular elongated flattened form, with a lateral lobular outline; and the calices are arranged in lines corresponding with the outer or longer boundary, and follow its lobular outline. There are three lines; but the middle one is very irregular. They are rather deep; and the septal costæ passing over the ridges between the lines give them a subcristiform aspect, somewhat as in *Oroseris* and *Dimorphastræa*. The septa and the septal costæ are regular, very delicate, and moniliform. There are three cycles of septa.

Height of the corallum 10 lines. Longest diameter of the calicular

surface 1 inch 6 lines; shortest diameter of the calicular surface 5 lines.

In a second and very much worn example the upright lobes, instead of being ranged in a line, are placed in a triangle. The third is regularly turbinate, tall, has a very oblique calicular surface, and is wholly destitute of wall or epitheca.

All these were taken from the lower reef at Crickley Hill.

THAMNASTRÆA FUNGIFORMIS, Edw. & Haime, Brit. Foss. Cor. pt. ii. p. 141, pl. xxx. fig. 3 (1851).

One specimen only has has come to my knowledge. It was obtained from the *Trigonia*-grit of Brown's Hill, near Seven Springs. It agrees with great exactness with the figure and description given by the original describers.

THAMNASTRÆA METTENSIS, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 141, pl. xxx. fig. 3 (1851).

Hitherto I have only met with this species in the lower reef at Crickley, and in the *Trigonia*-grit at Ravensgate and Leckhampton Hill.

THAMNASTRÆA DEFRANCIANA, Edw. and Haime, Pol. Terr. Paléoz. p. 110 (1851).

Astræa Defranciana, Mich. Zooph. p. 9, pl. ii. fig. 1 (1840).

All the specimens I have met with (and they are not numerous) were obtained from the lower reef at Crickley Hill.

THAMNASTRÆA TERQUEMI, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 140, pl. xxx. fig. 2 (1851).

Very few of the examples of this species have the regular turbinate form of the specimen figured by the original describers, the greater number being extremely irregular and having a very rugged method of growth.

They are commonly attached by a small surface of no definite form, from which they ascend and expand in joints rather than layers, which overlap on one side, but do not cover the previous growth on the other. The growth makes some of them very much like a pile of coins which have been pushed a good deal on one side.

The calicular surface often presents the figure of a rude triangle or lozenge, though sometimes it is oblong or crescent-shaped.

It is a common species in the lower reef at Crickley Hill; but the most rugose specimens have been obtained from the same zone near Cooper's Hill, where it appears to be equally abundant.

THAMNASTRÆA WALCOTI, Duncan, Supp. Brit. Foss. Cor. pt. iii. p. 19, pl. iv. figs. 5–10 (1872).

At present this species has only appeared in the lower reef. Specimens from the neighbourhood of Cheltenham differ from the figures and description given by Prof. Duncan, only in having the

corallum more thin and expanding and with a much more irregular outline.

I am indebted to my friend the Rev. P. B. Brodie for a very characteristic example of this coral, which he took from the coralliferous deposits at the Horse-Pools Hill, near Gloucester. The coral-bank there exposed is the equivalent of the one at Crickley Hill.

Genus Oroseris, Edw. and Haime.

This genus was associated by its original describers with the genus *Comoseris*, to which it really bears but a faint resemblance. As at present understood, it is a close ally of *Thamnastræa*; and some of the species are not easily distinguished from it; for the arrangement of the calices in lines, which may have either a radial direction or a concentric one, is often varied by the calices being evenly distributed, as in *Thamnastræa*.

The difference existing between those species in which the rows of calices assume a more or less radial course, and those in which they are disposed concentrically, is probably of more importance than at first sight appears. In those having the first arrangement, gemmation must have taken place more or less in connexion with the existing calices; but in the second a complete ring of septal costæ had been produced, bounding the upper surface of the corallum, and from these the new calices were produced.

Oroseris oolitica, n. sp.

The corallum is large, and very irregular in form. It is depressed, with the upper surface more or less gibbous and the under parts very irregular. The outer margin is thin, and a little wavy.

The basal wall is covered by a very strongly marked and wrinkled epitheca, which has deep concentric folds.

The mural costæ, when exposed by the abrasion of the epitheca, are numerous, delicate, and have many cuneiform synapticulæ.

The calices are for the most part placed in distinct linear grooves, though on some parts of the corallum they are scattered much as in *Thamnastræa*. In direction, the grooves irregularly follow the lines of the outer margin of the corallum. The longest furrow contains eight calices; but more commonly four or five are observable in a series. The ridges between the calices are not very prominent, but are obtusely rounded; and the septal costæ pass over them without any interruption or deflexion from their line. The furrows are about two lines wide.

The calices are from one line to one line and a half apart in the furrows, and they vary somewhat in their depth. The septa and septal costæ are rather crowded, irregular in thickness, and alternately more or less prominent; and this gives them the appearance of being alternately large and small; but where much rubbed down, they appear to be of nearly equal size. All have their margins distinctly but rudely tuberculated.

The only specimens I have met with were associated with Belemnites, in the compact yellow stone, about twenty feet below

the Pisolite at Crickley Hill, very nearly at the bottom of the exposed section; and they are the earliest oolitic corals I have met with, with the exception of *Montlivaltia lens*, which is found also in the *Cephalopoda*-bed.

OROSERIS CONCENTRICA, n. sp.

The corallum has a more or less turbinate form, and was attached by a small foot. The upper surface is either flat or more commonly a little concave; and the outline is generally of a rounded quadrangular form, with a thin and rather wavy edge. The under surface, which is the common wall, has a thin and generally very rudimentary epitheca, appearing as narrow concentric bands, but sometimes covering the walls in patches. The mural costæ are numerous, straight, parallel, and delicate, with very regular but not crowded cuneiform synapticulæ, which are not opposite to each other on contiguous costæ.

In the centre of the depressed calicular surface the calices are scattered about as in *Thamnastræa*; but they soon assume the linear arrangement peculiar to the genus, the furrows following in a considerable degree the outline of the corallum; but the subangular outline of the upper surface permits of their being often in straight lines without departing from their concentric disposition. In some instances the furrows run quite out at the edge of the corallum. The furrows are about two and a half lines wide; and the ridges between them are rather prominent, but much rounded.

The septa and septal costæ are straight, not crowded, very uniform in thickness throughout and with each other; they are delicate, and have on their margins very regular but not very closely placed tubercles, which are rather longer in the direction of the length of the costæ.

The calices are small and rather deep, with a tolerably well-defined but small fossula. They are about two lines distant from each other. About twelve septa appear in each calice.

The largest example I have yet seen has a calicular surface which is $2\frac{1}{2}$ inches across, and has a height of $1\frac{1}{2}$ inch.

It has been found in the lower reef at Crickley Hill and at Cooper's Hill, and is not rare.

OROSERIS CONTORTA, n. sp. (Pl. XVIII. fig. 17.)

The corallum is attached by a small surface, from which it either expands laterally, forming an elongated and curved figure, with the upper or calicular surface more or less crescent-shaped, or it becomes a very ill-defined turbinate figure, with a disposition to the growth of bulbous processes from its outer margin, or it has a more or less quadrangular calicular surface. Generally, however, the upper surface is elongated, with or without a crescentic curve.

There are numerous deep wrinkles in the epitheca, which is considerably developed.

The mural costæ are straight, and very equal in size. Compared with those of *O. concentrica*, they are more regular and a little

thicker. They have synapticulæ, which are so little developed that they have the appearance of little points, but they are very regular as to size and distance from each other.

The rows of calices run for the most part in the direction of the greatest length of the calicular surface. The greatest number I have seen in one series is five. They are deep, and have a small but deep fossula, which is without a trace of columella. The cycles are difficult to trace; but about sixteen septa enter into the formation of a calice.

The septa and septal costæ are somewhat equal in size and prominence; they are strongly papillated; and the latter, as is usual in the genus, have a subcristiform development between the rows of calices. They never anastomose. They are much less regular and delicate than in *Oroseris concentrica*, and their synapticulæ are very smooth and irregular.

It is found in the lower reef at Crickley, and small examples are common; and I have seen one from the same horizon at Cooper's Hill.

Oroseris incrustans, n. sp. (Pl. XVIII. fig. 16.)

The corallum is somewhat foliaceous and incrusting; and the upper surface, though corresponding with the surface of the object to which it is attached, nevertheless has a second or superimposed part of much smaller size than the one which it lies upon; and this gives to the corallum a slight central elevation. The outer margin, which has a somewhat rounded or subangular form, is closely adpressed, at no point showing the least disposition towards a leaf-like or upward curl.

The furrows are very numerous, short, and narrow, and the ridges between them of corresponding breadth. Not more than four calices appear in one furrow; and they are more frequently two or three together; but it is worthy of remark that on no part of the corallum are they scattered singly as in *Thamnastræa*. In direction the furrows follow roughly the outline of the corallum, and they are about $1\frac{1}{2}$ line apart.

The calices are $1\frac{1}{2}$ line apart; they are not deep nor very clearly defined. The septa and septal costæ are short, rather thick, of equal size and prominence, rather closely placed, and have their margins furnished with closely set and round tubercles. There are twelve septa in each calice.

The greatest diameter of the corallum is 3 inches.

One specimen only has been obtained, from the oolite marl (middle reef) at Sheepscombe by Mr. Wm. Jenkins of Cheltenham. It is attached to a large specimen of another species of coral.

Oroseris gibbosa, n. sp.

The corallum is much depressed and expanded, its under surface nearly flat, and its upper surface rising into rounded or elongated prominences or gibbosities, with corresponding deep hollows.

There is no epitheca; but the whole of the under part has flexuous and indistinct mural costæ.

No particular direction is observed by the lines of calices in this species. The longest furrows contain about seven or eight calices. They are shallow; but the ridges between them, though without much prominence, are much more angular than in the other species here described. They have a breadth of about two lines.

The calices are near together in the furrows, only one line apart, and are superficial. About twelve septa constitute the calice. The septa and septal costæ are thick, irregular, flexuous, sometimes quite crooked, often anastomosing, and not very closely placed. Their margins appear to have had irregular and rugged tubercles, which have been for the most part rubbed off.

A single specimen has been taken from the lower *Trigonia*-grit at Leckhampton Hill, by Mr. Wm. Jenkins of Cheltenham.

The foregoing five species of *Oroseris* may be easily distinguished from each other by the following very brief descriptions :—

O. oolitica by its size and very deeply wrinkled epitheca, and by the very unequal degree of prominence of the septa.

O. concentrica by its turbinate form, rudimentary epitheca, regular and delicate septal costæ, and concentric arrangement of the lines of calices.

O. incrustans by its incrusting habit, short lines of calices, and relatively stout but regular and closely placed septal costæ.

O. gibbosa by the irregular form of the corallum, absence of epitheca, and by its crooked, irregular, and stout septal costæ.

O. contorta by its distorted form, and by having the calices in rows rudely corresponding with the outer boundary of the calicular surface. It most nearly resembles *O. concentrica*, but has fewer calices, and longer as well as stouter septal costæ.

Genus Microsolena, Lamx.

Since the establishment of this genus by Lamouroux, in 1821, it has received at the hands of MM. Edwards and Haime such revision as was necessary to fit it for the reception of the group of perforate corals placed in it by them, the original describer not having fully understood its true structure and affinities.

Michelin, in his work on the fossil corals of France, while admitting the species on which Lamouroux had founded the genus, did not adopt the genus, but placed the type species in the genus *Alveopora*; and M'Coy, following Michelin, so far as the species is concerned, made use of the genus *Siderastræa*.

More recently Milaschewitsch has added much to our knowledge of the species of *Microsolena*, by pointing out the near relationship of the genus to *Thamnastræa*; and removing the latter wholly from the Fungidæ, he has placed it among the Poritidæ and in close proximity to *Microsolena*.

Microsolena porosa, Lamx. Exp. Méth. p. 65, pl. 64. figs. 24, 25, 26.

As yet I have met with only one instance of the occurrence of this coral in the Inferior Oolite. It was taken, by Mr. W. Jenkins of Cheltenham, from the lower reef at Crickley Hill.

Compared with the figure given by M. Lamouroux, it is less regularly turbinate, being more depressed and having the upper surface more convex. But in the number and distribution of the calices, and in the thinness and delicacy of the septa, it corresponds with great accuracy with the figure referred to. From the great thinness of the septa and their distance apart, the interseptal loculi have a breadth fully twice that of the septa themselves.

Microsolena regularis, Edw. and Haime, Brit. Foss. Cor. pt. ii. p. 122.

Alveopora microsolena, Mich. Icon. Zooph. p. 227, pl. lv. fig. 1.

It is with great doubt, on account of its stouter and more crooked septa, that I refer this species to the *M. regularis* of Edwards and Haime. It corresponds much more closely with Michelin's figure than with that given by Edwards and Haime; but when the septa are worn down they appear to be even broader than in his figure, and the interseptal loculi are reduced to the breadth of a mere line.

The figures given respectively by Lamouroux and Michelin of *M. porosa* and *Alveopora microsolena* are clearly those of two distinct species, though Edwards and Haime give the latter as a synonym of the former. It is doubtful whether *M. regularis* is not distinct from both. That the present species is identical with the one which furnished Michelin's figure, I have not, however, any doubt.

Hitherto I have only met with it from the *Trigonia*-grit at Ravensgate Hill, where it is not uncommon.

Microsolena, sp.

Several fragments of a species quite distinct from the preceding, and probably from all other oolitic species, have occurred at Crickley. They are characterized by their extremely rugged and crowded septa, and by the obscurity of their calices.

Genus Dimorpharæa, de From.

Dimorpharæa Lycetti, Dunc. sp.

Cyclolites Lycetti, Dunc. Supp. Brit. Foss. Cor. pt. iii. p. 23. pl. iii. figs. 7-9 (1872).

Dimorphastræa dubia, Tomes, Geol. Mag. vol. v. 1878 (not de Fromentel).

The examination of a specimen of *Dimorphastræa* from the Corallian of Nattheim, which I at first supposed to be the *D. dubia* of de Fromentel, but afterwards found to be *D. helianthus*, Becker, has satisfied me that I was in error in referring the Crickley species to it. The presence of a well-developed epitheca in the

latter would alone be sufficient to distinguish it from the Nattheim species. But it was not until, by the kindness of Dr. Holl, I had examined the type specimen of the *Cyclolites Lycetti* of Prof. Duncan, that I discovered that the Crickley coral I had referred to *D. dubia* was specifically identical with it. On removing some of the soft stony matter from the calicular surface of the figured specimen of *Cyclolites Lycetti*, a central large calice surrounded by a circle of smaller ones was revealed, and the true genus determined.

Prof. Duncan's specific name must, of course, on account of its priority, be retained.

The genus *Dimorpharæa* of M. de Fromentel has been created for such massive *Microsolenæ* as have a central large calice surrounded by smaller ones arranged more or less in circles. To it must be referred, as has been shown by Becker and Milaschewitsch, the *Dimorphoseris* of Duncan. The *D. oolitica* of that palæontologist, with the species I here introduce, make up five species of this genus, which is now for the first time made known as English.

DIMORPHARÆA PEDUNCULATA, n. sp.

The corallum is small, attached, fungiform, and supported on a narrow peduncle.

The peduncle is small at its attachment, but gradually expands upwards. The under surface of the fungiform part of the corallum is more or less concave; and both it and the peduncle are furnished with a thick and wrinkled epitheca which has concentric folds.

The upper surface is convex, in one specimen dome-shaped; and the outer margin is rather thin and overhanging.

The central or principal calice is large, round, and has exsert septa and a small and shallow but clearly defined and round fossula.

There are as many as two circles of calices around the principal ones, which are rather irregularly placed; and in the inner circle are one or two more developed than the others, and which make some approach to the size of the primary one. They are not at all closely placed in the circle; the spaces between them are nearly as great as the space between the circles.

The septa are very uniform in thickness throughout their length, and straight. There are three complete cycles and part of a fourth. Twelve principal septa, which are of uniform size, pass quite into the centre of the fossula, but do not unite with each other. The tertiary ones are fully three fourths the length of those of the primary and secondary cycles, and those of the fourth are only a little shorter. Some of those of the fourth run into those of the third cycle; but the twelve principal septa, which are visibly stouter than the others, maintain their independence throughout. All of them are distinctly moniliform.

Height of the corallum 8 lines, of which the peduncle takes one half.

Diameter of the corallum from 11 to 15 lines, of which the central large calice takes 3 lines.

One specimen was taken by me from the lower reef at the Horse Pools, Brookthorpe, near Gloucester, a few months since; and another was given to me by Dr. Wright, with other Inferior-Oolite corals from near Cheltenham as long ago as 1859. I have met with no others.

DIMORPHARÆA FROMENTELI, Tomes.

Thamnastræa Fromenteli, Tomes, Geol. Mag. vol. v. 1878.

I have found it necessary to remove this species from the genus to which I assigned it, and to place it with other species in the genus *Dimorpharæa*. A species of *Thamnastræa* from the Lias had already been named after M. de Fromentel, by MM. Terquem and Piette; but the alteration made above in the generic name renders a change of specific name unnecessary.

DIMORPHARÆA, sp.

A single specimen has been taken by myself from the lower reef at Crickley, which obviously differs from all the others here given. It is too ill preserved to admit of a detailed description, but may be briefly characterized as turbinate, higher than wide, with rather coarse rugged septa, and calices irregular both as to form and arrangement.

Genus PHYLLOSERIS, n. g.

The corallum consists of one or more upright foliaceous plates or fronds, which have a very irregular form, and are thin at their margin. One of their flat and upright surfaces is furnished with calices, which are arranged in transverse lines or bands running from side to side, a good deal as in the genus *Agaricia*. The spaces dividing these lines of calices from each other are covered by a membranous and wrinkled epitheca, which extends upwards quite to the margins of the calices. Generally the frond towards the bottom is wholly covered by epitheca.

The other surface of the frond is wholly covered by a transversely wrinkled epitheca without any trace of calices.

When the epitheca of the last-named surface is removed, long and delicate costæ are exposed, extending from the bottom to the top of the frond, and having a somewhat radiate arrangement.

The increase in the size of the fronds takes place by means of gemmation from their margins; but the increase in their number occurs quite differently.

They are produced by gemmation, which arises at variable heights on their calicular surfaces, generally about the point where the epitheca ceases to be uniform, and the rows of calices begin. The new frond is speedily covered outwardly by a wrinkled epitheca, its upper and outer part being calicular; and as it increases in size by gemmation it adapts itself closely to the parent frond,

and in time the young frond wholly covers the latter; and in that condition both the outer surfaces are wholly covered by a thick wrinkled epitheca, in which state calices are visible only at the edges of the fronds. But most commonly the new frond, long before it attains to the size of the original one, bears frond upon frond, like leaves, on its outer surface, and in this way a confused leafy mass is formed.

The calices themselves are much like those of *Thamnastræa*. Their septal costæ are continuous with those of other calices; and there is no columella.

The genus to which the present bears the greatest resemblance is *Protoseris*; but it differs wholly from this in the way which the fronds are produced, and in the presence of a strongly developed epitheca.

PHYLLOSERIS RUGOSA, n. sp. (Pl. XVIII. figs. 8–10).

A well-developed corallum consists of a flattened upright mass consisting of numerous vertical leaflets which may be classed as primary, secondary, tertiary, &c. They spring at different heights from the calicular surface of the primary frond, and afterwards successively in like manner from each other.

The primary frond, before the growth of the leaflets takes place, has the whole of the back surface divided into finger-like ridges, which have an upward and radiate arrangement, and are covered by a common epitheca wrinkled transversely. The front or calicular surface has its lower parts similarly enclosed by epitheca, which, gradually advancing upwards, forms narrow but prominent transverse bands between the rows of calices.

Gemmation takes place in these rows of calices; and new fronds are thus produced.

The epitheca continues its upward growth, and extends onto the young fronds; and finally all the calices are wholly obscured except those near the upper margins of the fronds.

The young fronds cling closely to the one from which they spring, completely smothering the calices; and they are in their turn grown over by a yet younger frond.

Two fronds of equal height face to face have some resemblance to the hands with the palms together, the backs of the hands and fingers not unaptly representing the mural surface of the fronds, and the palms the inside or hidden calicular surface.

The calices near the top of the fronds are quite different in shape from those lower down. They are often quadrangular or lozenge-shaped, and are distributed much as in *Thamnastræa*; but lower down they are divided into transverse lines by narrow bands of epitheca, and are round and have their outer margin so much produced that they become horizontal.

The septa are rather exsert; they are of nearly equal thickness, and, when numerous, have their margins very regularly geniculated.

There are three complete cycles and part of a fourth. Those of the first run into the centre and form a small columella, which is only visible in the worn calices. Those of the second are a little

shorter than the first; the tertiary ones are still shorter; and the septa of the rudimentary cycle are very short.

The septal costæ sometimes anastomose, and meet those of other calices at an angle.

The synapticulæ are small and numerous.

Diameter of the calices about 1 line.

The species occurs and is not uncommon in the lower reef at Crickley Hill, and the Horse Pools near Gloucester; but any thing like complete specimens are exceedingly difficult to procure, most of them being broken, or too thin to extract from the matrix.

PHYLLOSERIS, sp.

A small portion of the root of a species which only differs from *P. rugosa* in having much smaller calices, which are in rows having a vertical rather than a horizontal direction, has been met with at Crickley Hill. The septa are also much more moniliform, and probably porous from the effect of more numerous perforations. It is obviously quite distinct from the last.

Genus COMOSERIS, d'Orb.

COMOSERIS VERMICULARIS.

Mr. W. Jenkins, of Cheltenham, has forwarded to me a specimen of this species which he obtained from the lower reef at Crickley, which agrees with the specimens figured by MM. Edwards and Haime, except that the ridges are straighter and less numerous than they are represented to be in the figures given by those celebrated zoophytologists. There is a specimen also in Dr. Wright's collection.

CHORISASTRÆA OBTUSA.

Since the foregoing was written I have examined a large number of corals from the Great Oolite near Cirencester, amongst which were some specimens of *Thecosmilia obtusa*; and I find that these agree closely with some others from the *Trigonia*-grit at Birdlip and Leckhampton Hill. Probably the specimens which I made use of for comparison were a part of the same collection which furnished Prof. Duncan with the specimen from which his figure was taken*.

The occurrence of this species in the upper coralliferous bed of the Inferior Oolite, as well as in the Great Oolite, furnishes additional evidence of what Dr. Wright has advanced respecting their near palæontological relationship.

It appears to be to corals of this group that Quenstedt has applied the generic name *Cœnotheca*. Their mode of increase, however, which is wholly by gemmation, does not differ from that of the allied or perhaps identical *Chorisastræa gregaria*, and both must be referred to the same genus.

In conclusion I wish particularly to acknowledge the great assistance I have met with at the hands of friends when preparing the present paper. To Mr. T. J. Slatter, the companion of my visits

Supp. Brit. Fos. Cor.

to the famed sections of the Inferior Oolite near Cheltenham, and to Mr. W. C. Lucy, who has favoured me with some beautiful specimens from the Horse Pools near his residence, I am especially indebted, as also to Dr. Wright for the opportunity of inspecting the species which had received their names from the great zoophytologists MM. Edwards and Haime, and to Dr. Holl for his kindness in affording me the opportunity of examining specimens which had been described and figured by Prof. Duncan. Without such assistance this paper would have been much less complete.

EXPLANATION OF PLATE XVIII.

Fig. 1. *Chorisastræa gregaria*, the peduncle of a specimen before gemmation has taken place, natural size.

2. —— ——, a specimen a little further advanced in growth, and showing the elongated septa (costæ?) and the intervening loops.

3. —— ——, an example in which gemmation has taken place in the elongated septa (costæ?), the parent calice not having been interfered with.

4. *Cyathophyllia oolitica*, natural size.

5, 6. *Phyllogyra sinuosa*, the corallum of a small example, natural size.

7. —— ——, a portion of the calicular surface, magnified, showing the manner in which gemmation takes place.

8. *Phylloseris rugosa*, a portion of a frond, showing the lines and bands of calices separated by wavy ridges of epitheca, and showing a young frond with gemmation taking place along its upper edge. arising from it.

9. —— ——, a specimen showing the outer or epithecal surface, which has been completely covered by the epitheca and all trace of the calices obliterated.

10. —— ——, a few calices magnified.

11. *Confusastræa tenuistriata*, natural size.

12. *Thecoseris polymorpha*, natural size.

13. —— ——, some of the septa, showing the manner in which they anastomose.

14. *Thamnastræa Wrighti*, a few calices, magnified.

15. *Latimæandra Haimei*, some calices, magnified.

16. *Oroseris incrustans*, a portion of a corallum which is attached to a species of *Latimæandra*, natural size.

17. —— *contorta*, the corallum, natural size.

18. *Goniocora concinna*, a portion of a corallum, natural size.

19. —— ——, the calice, magnified.

Discussion.

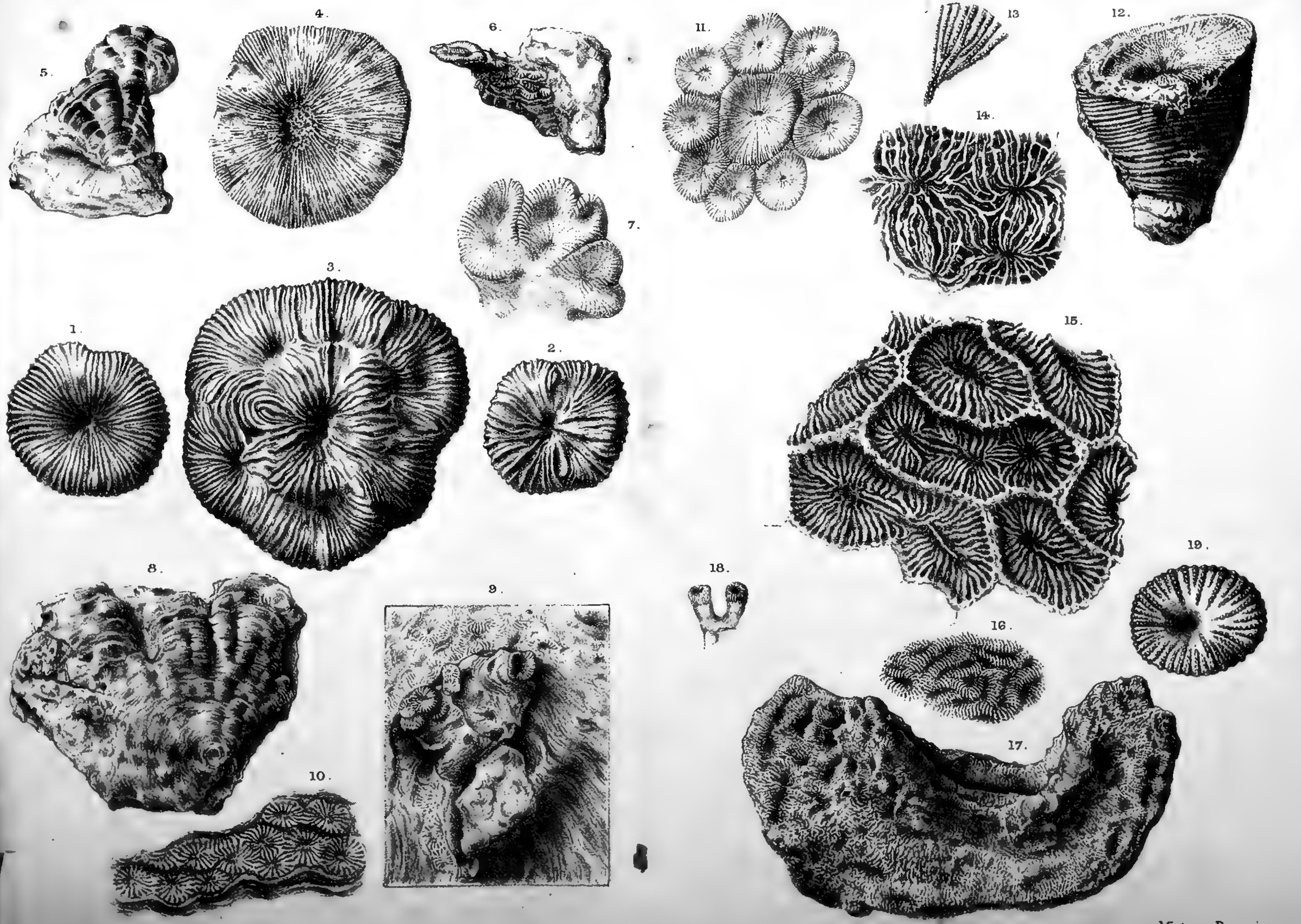
Dr. Duncan objected to the use of the term "reef," as the corals described from the Inferior Oolite grew on banks, and not on fringing or other reefs. He was satisfied that *Thecosmilia gregaria* and its varieties were found in the lowest and upper banks; and he did not concur with the author in placing this well-defined form under another genus. Reuss had shown the variability of the genus; and he himself noticed a specimen amongst those brought by Mr. Tomes in which there was budding high up, and a tendency to fissiparity. He objected to the statement that *Axosmilia*, *Montlivaltia Holli*, and *Donacosmilia* were identical, as the first had a

solid axial columella, and *Montlivaltia* had not. He was perfectly well aware of the difference between calicular gemmation and periodical increase of growth; and he maintained his statement, made in the Palæontographical Society's work, that *Montlivaltia Holli* increased by calicular gemmation. He did not consider the specimens marked *Confusastræa*, the *Adelastræa* of Reuss, to belong to that genus. After expressing his opinion about the great variability of corals, as proved during the late deep-sea researches, he condemned the practice of species-making unless there were very wide structural distinctions present. He stated that it was wrong to place *Thamnastræa* amongst the Perforata; for it only had perforate septa, a feature often seen in aporose corals. Its true position was amongst the Fungidæ.

The AUTHOR, in reply, maintained his views as to the identity of the *Axosmilia Wrighti* and the *Montlivaltia Holli* with the genus *Donacosmilia*. He insisted, on the grounds pointed out by Milaschewitsch on the truly perforate character of *Thamnastræa*, and insisted that the so-called *Thecosmilia gregaria* always increased by basal gemmation, and never by fissiparity.

A. S. Foord, del.

Mintern Bros. imp.



A. S. Foord, del. et lith.

Mintern Bros. imp.

INFERIOR OOLITE CORALS.

43. *The* Rhætics *of* Nottinghamshire. By E. Wilson, Esq., F.G.S. (Read June 21, 1882.)

At the Meeting of the British Association at York in 1881 I gave a summarized account of the Rhætic rocks of Nottinghamshire. In the present communication I propose to give a more detailed description of the same.

Rhætic rocks were first noticed in this district about fifteen years ago near Gainsborough, in Lincolnshire, by Mr. F. M. Burton, and were subsequently observed at Newark by the Rev. A. Irving and by Mr. Horace Woodward, and at Elton Station, on the Nottingham and Grantham line, by Mr. R. Etheridge. All these sections, however, were more or less incomplete, either above or below.

During the last five or six years several new and some complete sections of the Rhætic beds have been exposed on the eastern and southern borders of Notts, chiefly by new railway-works. Unfortunately these sections are now all covered up and grass-grown. Seeing, however, that they disclosed several interesting facts and some new features concerning this series, a brief record of them appears desirable.

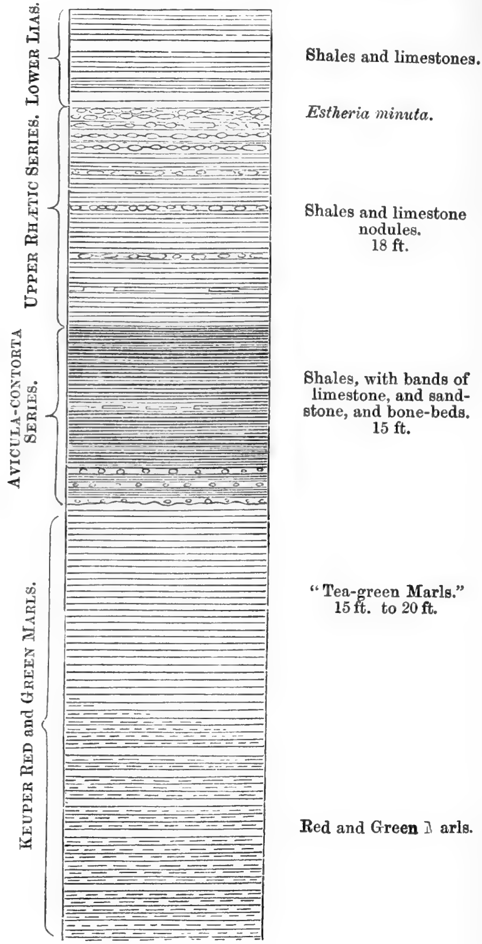
The Rhætic formation in this country is usually subdivided into three groups of rocks, viz.:—(1) *Lower Rhætic*, grey or green indurated marls, the "Tea-green marls" of Etheridge; (2) *Avicula-contorta* series, black fissile shales with subordinate bands of sandstone and limestone, with or without one or more "bone-beds;" and (3) *Upper Rhætic* or *White Lias*, a variable series of shales and light-coloured limestones. This tripartite subdivision has generally been considered to hold good for Nottinghamshire. In that county we get at the top a series of pretty thickly laminated grey marls with bands or layers of blue-centred septariiform nodules of limestone containing *Estheriæ*; below these come the characteristic thinly laminated black shales of the *Avicula-contorta* series; and beneath these we find a series of indurated unfossiliferous light-blue marls that weather a yellowish-green or buff colour, and break up into cuboidal fragments. For reasons presently to be given, I would take these lowest green marls from the Rhætics and relegate them to the Keuper formation (see figure, p. 452).

I now proceed to describe the chief Rhætic sections which are or have at different times been exposed in this district.

Gainsborough.—In the cuttings of the Great Northern Railway at Lea, near Gainsboro', the *Avicula-contorta* beds, represented by at least 25 feet of fossiliferous black fissile shales with several bands of micaceous sandstone and one or two bone-beds, may be seen resting "with conformable stratification" on "an eroded surface" of blue marl of the Upper Keuper series. The upper portion of the

cutting is occupied by glacial drift, which appears to cut out the higher beds of the Rhætics at this point. The Gainsborough section is remarkable for the exceptional development of the *Avicula-contorta*

Rhætics of Notts. Generalized Section.



beds, and for the numerous and thick bands of sandstone they contain. Mr. Burton, who has accurately described this highly interesting section in the pages of the Society's Journal*, then thought that the Rhætics (which had not at that time been discovered in Notts, Leicestershire, or Yorkshire) were limited to an area 3 or 4

* Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 315.

miles long by $\frac{1}{2}$ to 2 miles wide. The idea of such a localized extension along the strike is certainly erroneous and has since been abandoned. The southerly continuation of these beds in Lincolnshire is, indeed, indicated by the low escarpment which lies not far from the eastern bank of the Trent.

Newark.—Rhætics are exposed in the gypsum quarries on Beacon Hill, Newark, Notts. This section also is incomplete above. About 10 feet of "Paper-shales" (with casts of *Cassianella contorta* and *Axinus elongatus*), without any sandstones or bone-bed, are seen to rest *with a sharp line of demarcation* on light green marls 14 or 15 feet in thickness (the Lower Rhætics of some authors). These green marls appear to graduate down into the underlying red gypsiferous marls of the Upper Keuper series. Mr. Woodward, on having an old lime-pit in the Lias deepened, found the uppermost zone of the Rhætic series (White Lias) *in situ.*

The cuttings of the new Great Northern line between Newark and Bottesford, which for some distance roughly followed the Rhætic outcrop, exposed several good sections in these rocks.

Cotham and Kilvington.—At Cotham, 4 miles south of Newark, a complete section of the Rhætic rocks of the district was exposed. At the south end of the cutting the green marls of the Upper Keuper appeared, succeeded, going north, by *Avicula-contorta* shales (15 feet), with no sandstones or bone-bed and hardly the trace of a fossil of any kind, and these by Upper Rhætic marls (18 or 19 feet). At the road-crossing near the station, the northerly dip brought in Lower Lias, represented by 20 feet or so of limestones and shales, containing, amongst other fossils, *Ammonites planorbis*, *Modiola minima*, *Ostrea liassica*, *Pleuromya costata*, and *Lima gigantea*. About a mile further south Upper Rhætic marls were again seen capped by a few feet of Lias. In the next cutting further south (near Staunton Grange) the Rhætics were shut out by a fault which brought up Upper Keuper red marls on the south against Liassic strata on the north; but still further south, in the Kilvington cutting, Paper-shales reappeared just north of the road-crossing, succeeded by Upper Rhætic marls (17 or 18 feet) and capped by Lower Lias. In a limestone nodule from the top of the Upper Rhætic marls, I here found *Estheria minuta* in vast numbers. "Orston Spa," near by, is a ferruginous spring that is in all probability thrown out by a pyritic sandstone or bone-bed in the Paper-shales. At Elton station Upper Rhætic marls may be seen, succeeded by Lower Lias strata; and in the grass-grown cutting west of the station the Rhætic Paper-shales, with a bone-bed at the base, lie concealed.

Barnston.—At Barnston, 4 miles south of Elton, a capital section in the Rhætics was opened out during the construction of the new line from Bingham to Stathern. Here the Upper Keuper red gypsiferous marls, with the usual "Tea-green marls" above, were overlain, with the usual sharp line of division, by the *Avicula-contorta* shales (14 or 15 feet), containing a few thin bands of sandstone and a hard pyritic bone-bed, 1′ 6″ from the base, replete with the usual fish- and reptilian remains—amongst others *Ceratodus altus.* The

Avicula-contorta shales pass up into the Upper Rhætic marls (18 feet) and these are conformably overlain by a few beds of the Lower Lias containing the usual fossils of the zone of *Ammonites planorbis.* The description of the fossils of the shales and bone-bed of the *Avicula-contorta* series at Stanton, presently to be given, will equally well apply to Barnston, and so need not be repeated here. Between Barnston, Elton, and Orston, the Lias-capped Rhætics form a low but very clearly defined escarpment facing west, with a very palpable dip-slope towards the vale of Belvoir. At the boring for coal now in progress at Owthorpe near Colston Bassett, beneath 33 feet of blue shale of uncertain geological age, 14 feet of Paper-shales and then 19 feet of "Tea-green marls" were penetrated.

Stanton on the Wolds.—During the construction of the new Midland line from Nottingham to London, I noticed the Rhætics in the cutting at the north end of the tunnel at Stanton on the Wolds, between Nottingham and Melton Mowbray. The following section was exposed at that point:—

Section at Stanton on the Wolds.

		ft.	in
Post-Tertiary.	Boulder-clay with local intercalations of drift-sand, 50 ft. to	60	0
Avicula-contorta shales (Rhætic).	Shales dark-coloured, thickly laminated, with a few thin seams of sandstone and a band of nodular limestone 1 ft. 9 in. from base: *Cassianella contorta, Axinus elongatus, Protocardium Philippianum*	6	0
	Pyritic sandstone $\frac{1}{4}$ in. to	0	$2\frac{1}{2}$
	Shales darker and more thinly laminated than the overlying, with occasional streaks of fine white sand: *C. contorta, A. elongatus, P. Philippianum*	3	0
	Pyritic limestone, with *A. elongatus, Modiola minima,* fish-scales, sun-cracks $\frac{1}{2}$ in. to	0	1
	Shales black, fissile, with thin streaks of fine grey sand, 9 in. to	0	10
	Bone-bed, or coprolite-seam, soft white sand and quartz-pebbles: spines of *Nemacanthus filifer,* and *Hybodus,* sp.; teeth and scales of *Saurichthys acuminatus, Hybodus minor, H. reticulatus, Hybodus* sp., *Acrodus minimus, Sargodon tomicus, Ceratodus altus, Gyrolepis tenuistriata,* and various cestraciont palatal teeth; teeth and coprolites of *Ichthyosaurus platyodon, Ichthyosaurus* sp., and other reptilian and piscine teeth, vertebræ, bones, and coprolites	0	1
	Shales black, fissile, and earthy layers alternating	1	4
	Coprolite-seam, earthy; coprolites at wide intervals	0	1
	Shales black, laminated, with occasional reptilian bones...	1	3
Tea-green marls (Upper Keuper).	Light-blue marls weathering yellowish-green and breaking up into cuboidal fragments; base not seen	20	0

The Upper Rhætic marls were not seen *in situ*; but limestone nodules with *Estheriæ* were found in the overlying drift.

Comparison of this and the other Notts Rhætic sections with the Gainsboro' section leads me to conclude that the 15 feet or so of

Avicula-contorta shales in Notts comes on the same horizon as the middle portion of that series at Gainsboro'. I take that remarkable pyritic bone-bed which is identical in character and appearance at Gainsboro' and Barnston as fixing an approximately definite horizon in the Rhætic series. From this bone-bed upwards, if we allow evanescent seams of sand to thicken out into thickish beds of sandstone, the Stanton section roughly corresponds with the Gainsboro' section. Too much importance must not, however, be ascribed to "bone-beds" for the correlation of distant sections. In this instance the close similarity of these bone-beds is due to such a very variable process as the infiltration of mineral matter (bisulphide of iron). It must also be remembered that a bone-bed may be intensely hard and pyritic a few feet below the surface of the ground, and yet quite soft and friable at the outcrop, owing to atmospheric decomposition of the cementing iron-pyrites. This is, in fact, the case at Barnston, and is, no doubt, so elsewhere. Nor is it to be supposed that bone-beds in distant sections at about the same horizon are rigidly homotaxial; for since these beds were in all probability the resulting deposits of migratory shoals, and not of a universal swarm of fishes, a certain amount of time must be allowed for their transit from one place to another.

Now, as I have already said, I cannot admit that the green marls, which in this and the adjoining districts come below the *Avicula-contorta* shales, belong to the Rhætic series. For, whilst there is always a sharp stratigraphical line of division, with in some cases evidence of erosion, between the green marls and the Paper-shales, there is on the other hand every appearance of a gradation between the green marls and the underlying red and green marls of the Upper Keuper formation. Again, whilst there does not appear to be any essential difference in textural character between these green marls which come at the top of the Upper Keuper and those lower down in that series, there is a very decided textural distinction between the green marls and the overlying Rhætic shales. These green marls are, like the rest of the Keuper rocks, practically unfossiliferous; whereas with the very commencement of the *A.-contorta* beds we get evidence of the incoming of a decidedly marine fauna, including not only forms of life that characterize the Rhætic formation of Europe, but also *species* of mollusca and reptilia which range into the overlying Liassic strata. For these reasons, then, I am of opinion that in Notts and the adjacent counties, at any rate, the line between the Rhætics and the Trias should be taken at the base, not of the green marls, but of the *Avicula-contorta* beds.

The Rhætic rocks, as a whole, no doubt, form a stratigraphical as well as a palæontological passage-series between the Keuper and the Lias. This passage is apparent at some places in the West of England, *e. g.* in the splendid coast-sections at Watchet in the estuary of the Severn. There no hard and fast line can be drawn between the Upper Keuper beds and the Lower Rhætics: green and red marls may be seen alternating with black shales; and all are unquestionably as much Rhætic as Keuper. *Beneath* these "passage-

beds" are found in a general way 20 feet or so of green marls and calcareous marlstones (with or without red mottlings) which, under the term "Tea-green Marls," Mr. R. Etheridge, F.R.S., has proposed to class with the Rhætics*; and in this classification he has, as a justly high authority on all that pertains to these beds, been followed, though by no means universally, by other geologists†. The late Mr. Charles Moore, another high authority on Rhætic geology, also appears to have been of this opinion. For reasons identical with those stated above, I am inclined to agree with Dr. Thomas Wright, F.R.S., and others, who consider that these "Tea-green Marls" properly belong to the Keuper formation‡. However this may be, it will not materially affect the question of the age of the similar beds in Notts; for it would be impossible to prove that the "Tea-green Marls" of the West of England were homotaxial with the green-coloured marls that occupy the same relative position beneath the *Avicula-contorta* shales in that county. Probably in both districts these green marls were once red in colour and non-calcareous, and have since become bleached and calcareous in part by the downward infiltration into them of some deoxidizing chemical agent and carbonate of lime, derived from the decomposition of the abundant organic remains of the overlying *A.-contorta* shales. The very general occurrence of 20 feet or so of "greenish marls" at the top of the Keuper-marls in this country, is a coincidental result of discoloration§. Neither the textural characters, the stratigraphical relations, nor the organic remains of these beds, justify us in separating them from the rest of the Keuper formation and classing them as Rhætic.

Discussion.

Rev. A. Irving said that the division of Mr. Wilson was the same as that adopted by the German geologists. He also knew the district well, and could confirm Mr. Wilson's statement as to the erosion at the base of the *Avicula-contorta* zone, and agreed with the propriety of adopting this line of division.

* Proc. Cotteswolds Naturalists' Field Club, 1864. Trans. Cardiff Nat. Soc. vol. iii. pt. 2, 1872.

† "Rhætics of Leicester," by W. J. Harrison, F.G.S., Quart. Journ. Geol. Soc. 1876. Sketch of the Geology of Lincolnshire, by W. J. Harrison, F.G.S., 1882. Geology of England and Wales, by H. B. Woodward, F.G.S., 1876.

‡ Monograph of Lias Ammonites, by Dr. Thomas Wright, F.R.S., Pal. Soc. Memoirs, 1880, &c.

§ The thickness of the Green Marls, both in the Midland counties and in the West of England, *varies* appreciably at different places not far distant (10 to 30, or ?80 feet at Camel Hill). The occasional presence of red blotches in these green beds indicates that they were once red beds that have been stained green, not green beds that have been stained red.

44. *On* Thecospondylus Horneri, *a new* Dinosaur *from the* Hastings Sand, *indicated by the* Sacrum *and the* Neural Canal *of the* Sacral Region. By Prof. H. G. Seeley, F.R.S., F.G.S. &c. (Read June 21, 1882.)

[Plate XIX.]

Dr. A. C. Horner, of Tonbridge, has obtained from the quarry at Southborough in the Hastings Sand, and intrusted to me, what I believe to be a unique specimen, so far as this country is concerned, exhibiting a mould of the entire neural cavity of the sacral region of a Dinosaur. But the specimen is nevertheless peculiarly tantalizing, since the quarryman states that it is the only specimen of any kind that he has ever found in the quarry, and enough remains of bony tissue upon the cast to render it certain that the external mould of the sacrum, if not the bony tissue itself, might have been preserved. It is imperfect both anteriorly and posteriorly, but measures exactly 60 centimetres in length. The vertebræ which are complete are five in number; each is 11 centim. long; but there is a small fragment in front which appears to show that there was another vertebra anteriorly (fig. 2, 1), while the fragment of the posterior vertebra (fig. 2, 7) admits of no question. We have thus a sacrum which certainly included six or seven vertebræ, and may have comprised more. The bony tissue is preserved only upon the right side of three consecutive vertebræ. It is a thin film closely adherent to the cast, showing a cancellous structure external to the thin interior layer (fig. 1, *b*). This film is not more than from 1 to 2 millim. in thickness, and therefore gives no clue to the form of the sacrum; though other evidence leads me to believe that the bone was extremely thin, and pertained to an animal closely allied to *Ornithopsis*.

The neural chamber of this sacrum, besides being remarkable for its great length, is singularly compressed from side to side (fig. 2), and expanded from below upward (fig. 1). It is at first sight no easy task to distinguish the back from the front. In *Anoplosaurus curtonotus* I figured the neural canal of a Dinosaur (Quart. Journ. Geol. Soc. vol. xxxv. pl. xxxiv.), which seemed to prove that the anterior third of the neural canal is the part which has the greatest transverse expansion. Subsequently Prof. Marsh (Am. Journ. Sci. vol. xxi. pl. 6, 1881) figured a cast of the neural cavity of *Stegosaurus*, in which the sacral canal is about 26 centim. long, and, where highest, 7·6 centim. high, and 4·3 centim. wide in front.

Anoplosaurus from the Cambridge Greensand had the sacral nerves of moderate size; but the casts of the foramina between the vertebræ, which are represented in Professor Marsh's plate, are deep and narrow, and two of them extend the entire height of the neural cavity. In regarding the larger portion of the sacrum as anterior, we follow what may be termed Dinosaurian precedents; and when we

observe on the sides of this specimen large vertical eminences (fig. 1, *t*), which resemble those figured by Prof. Marsh, we might be tempted to suppose that here too were intervertebral foramina, were it not that a large transverse process (figs. 1 & 2, *t a*) is preserved which exactly fits on to one of them. This transverse process is a cast in sandstone without a trace of bony tissue; but, from the sharpness of its contours, it assists in demonstrating the conclusion that the bony substance of this sacrum must have been of extreme thinness. The true intervertebral foramina pierced through the middle of the vertebræ, and are small transversely oval apertures with sharp clean margins (fig. 1, *v*), such as could only have been left by a thin film of bone having been removed. The junctions of the vertebræ appear to have been complete, so that no aperture existed in the sutural line of the vertebræ. The width of the cast (fig. 2) below the first foramen is 1·7 centim., below the second it is 1·6 centim., below the third it is 2 centim., below the fourth it is 1·8 centim., below the fifth it is 1·2 centim., and was evidently less in the next succeeding vertebra. These foramina lie in a straight line (fig. 2); and the cast expands below them in depth as though it sunk into the bodies of the vertebræ; but this depression is very small in amount, as is evidenced by the very gentle convexity in length of the base of the specimen; but superiorly the cast expands in a remarkable way in a convex curve, which, however, is flattened over each neural arch (fig. 2).

The anterior part of the first vertebra, of which the centrum is preserved, is broken away, so that its depth at the foramen cannot be given with certainty; it was probably about 4·5 centim. Over the second foramen (fig. 1, 3) the depth is 7·5 centim., over the third (fig. 1, 4) nearly 8·5 centim., over the fourth (fig. 1, 5) 6·7 centim., over the fifth (fig. 1, 6) 4 centim., while the next appears to be diminishing further. Thus this neural canal is distinguished from all forms hitherto known by its extraordinary lateral compression relatively to height in the middle region.

The foramina appear to be situate at about the middle of the neural canal in front, below the middle in the next three vertebræ, and above the middle in the last preserved.

The first foramen does not differ greatly in length from the others; it is under 2 centim. long, of ovate form, and 1 centim. deep. Its outlet is vertical above and oblique posteriorly. The second foramen is deeper, and opens obliquely posteriorly; the third foramen is narrower than the first, and pointed in front and behind. The fourth is large, and the fifth small and narrow. In every case except the last the neural canal is wider above the foramen than below it.

The base of the specimen is rounded from side to side with a slight longitudinal median groove behind (fig. 2), and with an expansion or swelling in the region of the sutures between the vertebræ. The rounding is most marked in the middle of each centrum; and in front there is a slight approach to flattening. The nutritive foramina (fig. 2, *n*) are well seen in the first vertebra preserved; they are narrow, 1 centim. long, 1 centim. apart, and 5 centim. from the anterior margin. In the next two vertebræ they are much smaller and less

distinctly marked; in the fourth they are smaller still, but wider apart, and still preserve the same distance from the anterior border of the vertebra. In the sixth they become large again, are less than a centimetre apart, and a little more anterior in position.

The sutural line between the vertebræ shows that in the region of the centrum the outline was convex from above downward in front laterally, and concave from side to side at the base in front. The sutures between the vertebræ are marked by sharp narrow grooves, which correspond to ridges on the interior of the bone. The suture appears to pass upward, so as to merge into the neuro-central suture, which is faint, but best marked in the last vertebra, where it passes below the lateral neural foramen. The antero-posterior limits of the neural arch correspond closely to the limits of the centrum.

The transverse processes are directed forward in front, outward in the middle, and backward behind (fig. 2). They are given off, as nearly as may be, in the line of the lateral intervertebral sutures, and just in front of the sutures on the base. There is no evidence of any separate bony base to these processes, separating them from the neural canal, though such partitions probably existed. The first of these processes on the right side is at the fracture $4\frac{1}{2}$ centim. deep, and widens from 1 centim. above to $2\frac{1}{2}$ centim. below. It is situate just in front of the intervertebral suture.

The attachment of the second process is 4·8 centim. deep, with its base placed a little higher than the first. Its margin is concave in front; and the concavity appears to have excavated the process much as in the first process. The third process is fractured nearer to its base, and is less than 4 centim. deep and about 2 centim. wide. The fourth is smaller; the fifth, hardly more than $1\frac{1}{2}$ centim. deep and 1 centim. wide, diverges conspicuously backward and outward.

The first process on the right side expands outward and forward in a subconical way, so as to terminate in a large flattened facet for the ilium (fig. 1, *t a*), which is vertical in position, though inclined somewhat forward, and a little convex from above downward. It is 11·5 centim. deep and 7·5 centim. wide where widest. The posterior border is convex, and the posterior side gives off a little rounded ridge where it joins the side of the cast of the neural region. In front the outline of its articular end is more angular, being compressed below and above. A blunt ridge runs on the inner side from the middle, and expands upward so as to form the superior part of the transverse process at its base, in such a way as to give an aspect to the process of being excavated in front.

The transverse processes would give a width to the sacrum in front of 20 centim., which was probably increased towards the middle.

Behind the transverse processes there is a moderate circular inflation of the cast, which is conspicuous in all the vertebræ, so that in front of the neural foramen there is a somewhat convex rugose tubercle, as though bone were attached to it.

I cannot speak with any certainty of the affinities of the remark-

able animal thus indicated; for if my inference from the condition of the transverse process is correct, it belongs to a very different type of animal from the Dinosaurs hitherto known, which have heavy vertebræ in the sacral region. The only English genus (*Ornithopsis*) which has pneumatic vertebræ and dense bony tissue, must be assumed, from the allied American genera, to have had a sacrum of very different character. There is no proof that the vertebræ of *Thecospondylus* were pneumatic; but the bones were formed on the lightest type that I have yet seen, and indicate, I believe, an ordinal or subordinal group, in which the skeleton was not pneumatic, but as dense and light as in the Ornithosauria, and supported on powerful hind limbs.

With an enlightened liberality which deserves our thanks, Dr. Horner has commissioned me to deposit the specimen in the national collection at South Kensington, that it may be the better available for study.

EXPLANATION OF PLATE XIX.

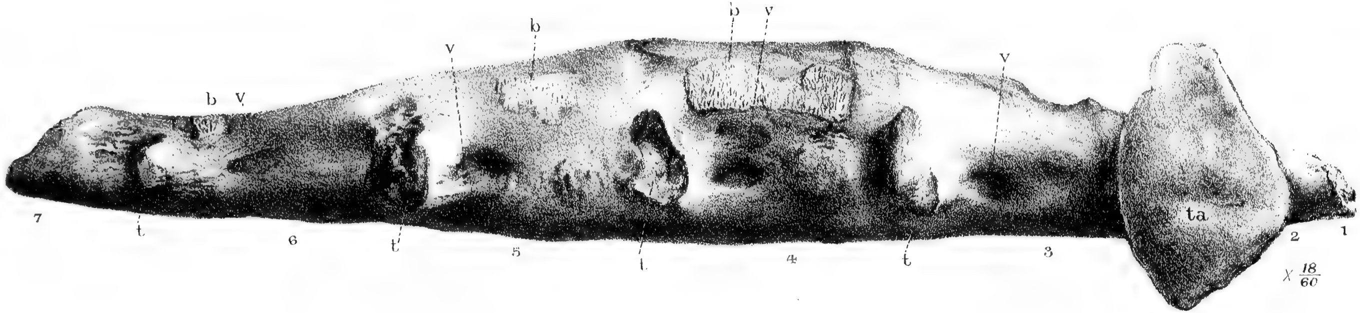
Fig. 1. Right lateral aspect of cast of neural cavity of sacrum, showing:—the sequence of vertebræ, numbered 1 to 7; the bases of the transverse processes (*t*) on the 3rd, 4th, 5th, and 6th vertebræ, and the large expanded articular facet of the 2nd transverse process (*t a*) where it joined the ilium; the apertures (*v*) for the passage of sacral nerves; and (*b*) portions of thin dense bone adherent to the neural region of the vertebræ numbered 4, 5, and 6.

2. Inferior aspect of the same specimen, showing the rounded underside of the bodies of the vertebræ, their attenuation posteriorly, the sutures (*s*) between the bodies of the vertebræ, the positions (*t*) from which the processes are given off and their divergence backward in the 6th and forward in the 2nd; the positions of the vascular foramina are indicated by the letter *n*.

Discussion.

The President agreed with the author in regarding the specimen as indicating the existence of a new genus.

1.



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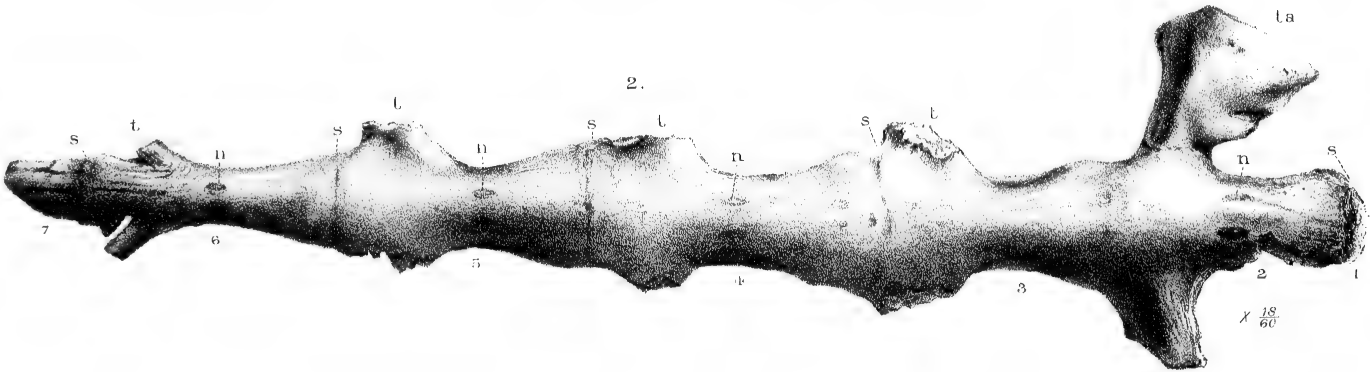


Mary Suft, lith. Mintern Bros. imp

THECOSPONDYLUS HORNERI.

45. *On the* Relations *of the* Eocene *and* Oligocene Strata *in the* Hampshire Basin. By Prof. John W. Judd, F.R.S., Sec. G.S. (Read April 26, 1882.)

I. *Introduction.*

Since the publication of my paper "On the Oligocene Strata of the Hampshire Basin" *, I have been favoured with many valuable suggestions and criticisms from geologists, both in this and other countries; and the time has now perhaps arrived when some of the interesting questions thus raised may be discussed with advantage.

The great object of my former memoir was to determine the age and relations of a series of marine beds which contain a highly interesting fauna—a fauna presenting the closest affinities with that of a well-defined system of strata very widely distributed in Central Europe.

In framing his classification of the Hampshire Tertiaries, the late Prof. Edward Forbes gave no place to this important series of beds—a fact which does not seem to have been sufficiently considered by those among my critics who have demurred to my proposed modification of Forbes's classification as unnecessary and, therefore, unwarrantable.

The history of the discovery of this interesting marine series does not appear to be generally known. The late Sir Charles Lyell spent his earliest years in the New Forest, residing at Bartley Lodge near Lyndhurst. At that time shelly marls appear to have been in great request among agriculturists, being employed by them as a manure on some of the poorer soils, like the similar materials of the French Fahluns and our own Crags. Now, in the hills lying on the north side of the town of Lyndhurst such marls were found to occur, and numerous pits were opened for their excavation. In his visits to these marl-pits Lyell found the beds to be crowded with beautiful and well-preserved marine shells, of which he made a considerable collection, sending examples of them to Webster and Sowerby.

At that time all the marine bands which occur in the Hempstead, Bembridge, and Headon series were confounded with one another under the name of the "Upper Marine Formation;" and it is not surprising, therefore, that Webster at once claimed these marine marls of Lyndhurst as being of that age †. Sowerby, however, seems to have recognized the fact that the fauna of the Lyndhurst beds is a peculiar one; and he described and figured two of the most remarkable and distinctive of its fossils, namely *Voluta geminata*, and *Cardita deltoidea* ‡.

The employment of these marls, or shelly clays, of the New Forest for agricultural purposes soon ceased, however; but the numerous abandoned workings and the names given to certain

* Quart. Journ. Geol. Soc. vol. xxxvi. (1880) p. 137.

† Trans. Geol. Soc. 2nd ser. vol. i. p. 94.

‡ Min. Conch. t. 398. f. 8, t. 259. f. 1.

localities prove to what an extent it was at one time carried. Fragmentary specimens of the fossils of these beds may still be found in the old workings; but the late Mr. F. Edwards, in bringing together his fine collection of the Mollusca from the British Lower Tertiaries, found it necessary to emply workmen to reopen some of these pits, in order to obtain well-preserved specimens. There were also at that time two brickyards in which the strata in question were exposed, those namely of Whitley Ridge and Roydon, the former of which has been long closed.

But in the year 1858 the construction of a railway-cutting at Brockenhurst afforded an opportunity for collecting the fossils of this interesting series of marine beds, of which opportunity Mr. Edwards and the Geological Survey made excellent use; Mr. Henry Keeping and Mr. Richard Gibbs, the fossil-collector of the Survey, were both for some time employed in collecting the fossils from this interesting deposit.

In 1863 M. von Könen visited this country: and in the group of fossils which Mr. Edwards had collected from Lyndhurst, Whitley Ridge, Roydon, and Brockenhurst he at once recognized the peculiar and remarkable fauna of the Tongrian of Belgium and the Lower Oligocene of Northern Germany. He also placed on the same horizon certain beds at Colwell Bay and Whitecliff Bay in the Isle of Wight *.

Dr. Duncan's subsequent study of the rich coral-fauna of these beds amply confirmed Von Könen's views as to their Lower-Oligocene age †.

Now in my former memoir I have argued that the Barton Clay and its continental equivalents ought to be regarded as forming the highest member of the Eocene. The Headon-Hill Sands and Clays, which overlie the Barton beds, exhibit intercalated bands of brackish-water origin, and yield a considerable fauna. Among the most abundant and characteristic fossils of both the Headon Sands and Clays are the different varieties of *Cerithium concavum*, Sow. In many parts of the continent a series of beds with a similar fauna has been found, overlying the richly fossiliferous representative of the Bartonian; and this series of strata has long been recognized by Mayer, Sandberger, and other authors as "the zone of *Cerithium concavum*." To this horizon, therefore, I have referred both the Headon Sands and Clays.

The richly fossiliferous marine beds of Lyndhurst and Brockenhurst I believe to altogether overlie the Headon group or Zone of *Cerithium concavum*: and I have proposed for it the name of "the Brockenhurst series," inasmuch as it constitutes a mass of strata of considerable thickness and importance, and possesses a very rich and characteristic fauna. I have grouped the Headon and Brockenhurst beds together as the Lower Oligocene, and the overlying Bembridge and Hempstead as the Middle Oligocene, the Upper Oligocene being altogether wanting in this country.

* Quart. Journ. Geol. Soc. vol. xx. (1864) p. 98.
† Monograph of British Fossil Corals, 2nd ser., Pal. Soc. 1866.

To this proposed classification exception has been taken by various critics, on very different and often quite opposite grounds. Many esteemed continental correspondents, who entirely agree with me as to the order of succession of the strata, point out that in the Paris basin the zone of *Cerithium concavum* appears to be simply an upper and subordinate member of the Bartonian; they argue, therefore, that the line of separation between the Eocene and Oligocene should be drawn at the base of the Brockenhurst series, thus including the Headon Clays and Sands in the Bartonian or Upper Eocene. My reason for not, in the first instance, adopting this line as the limit of the Eocene and Oligocene was the great inconvenience which would result from breaking up our fluvio-marine series into two portions, and grouping one with the Eocene and the other with the Oligocene. It is true that the interesting observation made by Messrs. Keeping and Tawney, that at Whitecliff Bay an actual unconformity appears to exist at this horizon, lends some support to the view that this is the line of demarcation between the two great series; and, in order to prevent the inconvenience of adopting different limits between the great geological divisions in this country and on the continent, it may be advisable to waive the objection to breaking up what appears to be, locally, a natural grouping of the strata.

But other critics, while agreeing with M. von Könen, Dr. Duncan, and myself as to the Lower-Oligocene age of the Brockenhurst beds, maintain that I have altogether misunderstood the order of succession of the strata *. They assert that the Brockenhurst beds do not overlie the Headon group, but lie in the midst of it, forming a basement bed to the so-called "Middle Headon series." To the very obvious objection that this places what nearly all continental palæontologists regard as an Upper Eocene fauna below one belonging to the Lower Oligocene, one of the authors has replied by asserting that the name of the zone of *Cerithium concavum* is properly applicable only to the sands at the base of the Headon series, and not to the overlying clays †. More matured study of the question, however, appears to have led Mr. Tawney to greatly modify his views on the whole question; for in a later memoir we find him maintaining that the term Oligocene "is less applicable to the English Tertiaries than the older and more classical division into Eocene &c.," and, again, "the break between Oligocene and Eocene is an unnatural one, and the introduction of the term in our opinion obscures the affinities between the members of the English series" ‡.

In the same paper this author abandons his former views as to the English representatives of the zone of *Cerithium concavum*, and states that the Headon Sands are characterized by the *Cerithium pleurotomoides*, Desh., while he now admits that *Cerithium concavum* is especially abundant in the overlying clays. With the great

* "On the Beds of Headon Hill and Colwell Bay in the Isle of Wight," by H. Keeping and E. B. Tawney, Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 85.

† Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 127.

‡ Proceedings of the Cambridge Philosophical Society, vol. iv. p. 147, note.

majority of continental palæontologists, I maintain that *Cerithium concavum* and *C. pleurotomoides*, are mere varieties of one well-marked species, and that both the Headon Sands and Clays belong to the zone of *Cerithium concavum*.

In the discussions which have taken place with respect to these Lower Tertiary strata, two perfectly distinct questions are involved—first, as to the order of succession of the beds in the Hampshire basin, and, secondly, as to the correlation of those beds with the deposits formed during the same great geological periods in other areas.

It will manifestly facilitate our fair consideration of these two questions, if we treat each of them separately; and such a course is fortunately rendered possible by the fact that at Whitecliff Bay, in the Isle of Wight, we have a continuous section of about 1900 feet of nearly vertical strata belonging to the Eocene and Lower Oligocene periods; so that here, at all events, the matter is not complicated by any doubt as to the true order of succession. The vertical position of these beds is not very favourable for the collection of fossils from them; but many of the strata are admirably displayed at low water, especially during spring-tides, and yield rich and abundant faunas. The admirable section of Professor Prestwich* enables us to refer without risk of being mistaken to any particular stratum; and the thicknesses of the whole of these beds have been carefully corrected by Mr. Codrington with the aid of the 25-inch maps of the Ordnance Survey †.

I am greatly indebted to Mr. Codrington for the loan of the manuscript of his detailed section of the beds seen in Whitecliff Bay, which has been of great service to me in my studies.

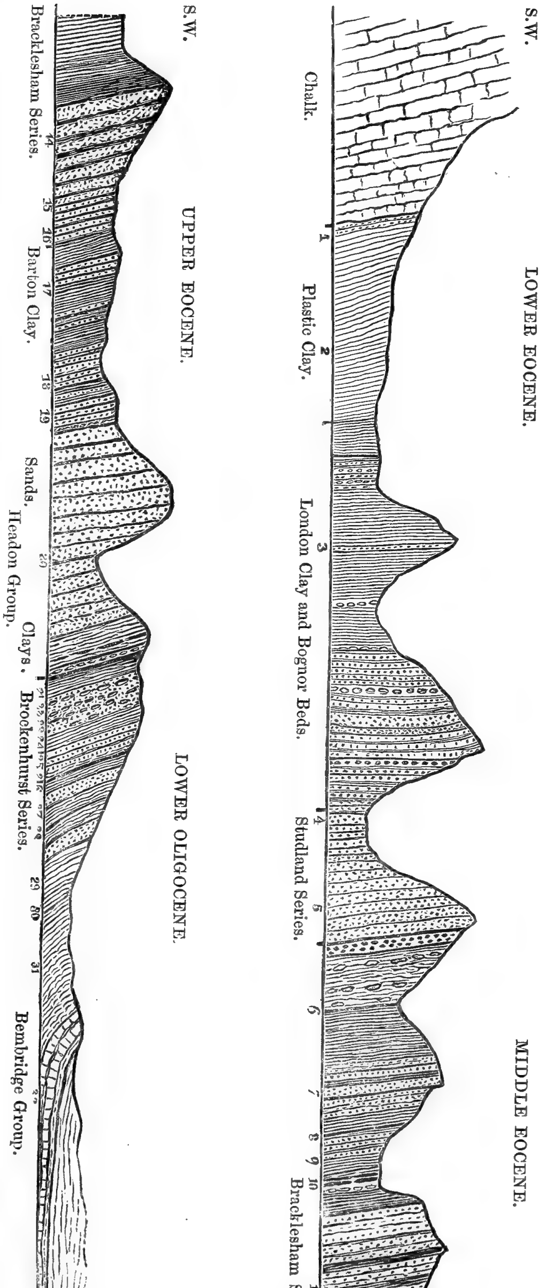
II. *Geological Age of the several Series of Beds exhibited in the Whitecliff-Bay Section.*

The references made to the several portions of the Whitecliff-Bay section in the following pages will be facilitated by the accompanying woodcut (p. 465), in which the nature of the several beds is indicated by shading. The engraver, in reducing the section to the limits of the page, has not very accurately preserved the relative thickness of the several beds. These thicknesses, however, are stated in the text. The numbers are those of Prof. Prestwich's section.

With respect to the portion of the Whitecliff-Bay section which represents the Lower Eocene, there is fortunately little ground for difference of opinion. The widely distributed Plastic Clay series of the Paris, Hampshire, and London basins is, at Whitecliff Bay, represented by Mr. Prestwich's bed 2, here 200 feet in thickness, and is seen to be overlain by a series of sands and clays (beds 3 and 4 of Prestwich) with a tolerably abundant fauna. That this series of beds, which is about 300 feet in thickness, is correctly referred to the London Clay has been shown by the valuable researches

* Quart. Journ. Geol. Soc. vol. ii. (1846) pl. ix.
† *Ibid.* vol. xxiv. (1868) p. 519.

Section in Whitecliff Bay, Isle of Wight.



of Mr. Meyer * and Mr. Caleb Evans † concerning the equivalent strata which were exposed during the Portsmouth-Dockyard extension works. The Portsmouth sections, as described by these authors, supply us also with the means of bringing into correlation the fossiliferous rocks of Bognor, the stratigraphical position of which was before uncertain, and the beds of the Whitecliff-Bay section, which have not yielded a very abundant fauna.

When we proceed westward, however, to Alum Bay, which is distant 22 miles from Whitecliff Bay, there is more difficulty in determining the exact limits of the Lower Eocene. The carefully measured section of the Geological Survey shows the Plastic Clay to be only 84 feet thick, while it assigns 219 feet of strata to the London-Clay series. Mr. Gardner ‡ has argued in favour of including the next 176 feet of strata in the London-Clay series; and there are good grounds for adopting his suggestion. This would make the Lower Eocene beds at Alum Bay 480 feet thick, while at Whitecliff Bay they are 500 feet. Both the divisions of the Lower Eocene are represented at Studland Bay: but the characters of the exposures are not such as to readily admit of the relative thicknesses of the series of strata being accurately determined.

But when we come to the Middle Eocene strata, we find the greatest diversity between the views of different authors, both as to the limits of the several divisions and their correlation with the strata of the London and Paris basins respectively.

In 1847, Mr. Prestwich announced his very important discovery that the Bracklesham and Barton beds of the Hampshire basin do not represent, as had formerly been supposed, the London Clay, but that the former is the exact equivalent of the Calcaire grossier, and the latter of the Grès de Beauchamp, or Sables moyens, of the Paris basin §. Contemporaneous with this important determination was the same author's recognition of the Lower Bracklesham fauna in the Middle Bagshot strata of the London basin ||.

Above the strata which at Whitecliff Bay have been shown to be the representatives of the London Clay, there occurs a series of unfossiliferous sands (Bed 5 of Prestwich), in all probability of freshwater origin. The thickness of these beds has been estimated at 142 feet by Mr. Codrington; and they were correlated by Prof. Prestwich with the Lower Bagshot series in the London basin.

The beds numbered from 6 to 14 by Prestwich were, with the exception of the upper 9 feet, referred by that author to the Bracklesham series, which, as thus defined, had a thickness of about 450 feet. The beds 15 to 19 inclusive, in all about 260 feet of strata, were referred to the Barton Clay. But in 1862 the Rev. O. Fisher proposed to remove more than 200 feet of the Whitecliff-Bay beds from the Barton series and to include them in the Bracklesham

* Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 74.
† Proc. Geol. Assoc. vol. ii. pp. 61, 149.
‡ *Ibid.* vol. vi. p. 86.
§ Quart. Journ. Geol. Soc. vol. iii. (1847) p. 353.
|| *Ibid.* p. 378.

series *. Mr. Fisher's reason for proposing this great change in the classification of the Whitecliff-Bay beds was that he considered certain fossiliferous bands could be traced continuously wherever the Bracklesham series is exposed over the whole Hampshire basin. In each of these fossil-beds, which vary in thickness from 6 inches to 6 feet, he assures us that a similar matrix and the same assemblage of fossils can be recognized, and he assumes the continuity of these fossiliferous bands over the whole of the wide area through which the Bracklesham series can be followed—an area measuring 40 miles from east to west, and 20 miles from north to south.

But it is only fair to remember that the occurrence of these fossil-beds is capable of a different explanation. Among the inconstant strata deposited (as the Brackleshams undoubtedly were) near the estuary of a great river, similar materials with the same assemblage of fossils would be deposited wherever the same physical conditions prevailed; and it is not necessary to assume that similar fossil-beds exposed at widely separated localities are necessarily parts of one continuous stratum. Mr. Fisher's argument in favour of including so great a thickness of the Whitecliff-Bay beds in the Bracklesham series rests to a great extent also on his reference of the fossiliferous strata of Hunting Bridge to that geological horizon; and this is a conclusion which is far from being free from doubt. Although it is difficult among the poorly fossiliferous beds of Whitecliff Bay to fix the exact line of demarcation between the Bracklesham and Barton series, yet there are good grounds for believing that the Barton Clays have a greater thickness and importance at that locality than is ascribed to them by Mr. Fisher.

With respect to the correlation of the richly fossiliferous strata of the Hampshire and Paris basins, Mr. Prestwich's admirable papers left little to be accomplished, and the discovery of fresh species in the two areas has completely confirmed the conclusions arrived at by that author with the assistance of Prof. Morris and the late Mr. F. Edwards. As early as 1847 † it was proved that the Bracklesham beds contain the same fauna as the Calcaire grossier; and in 1857 the exact correspondence of the Bracklesham series and the Barton series with the Middle and Upper Eocene of France and Belgium was established beyond all chance of controversy ‡.

But the correlation of the richly fossiliferous Hampshire beds with the barren Middle Eocene of the London basin has proved a far more difficult task; and the views generally accepted on this question are, to say the least of them, still open to very grave doubt.

The Lower Bagshot beds of the London basin have a thickness of from 100 to 150 feet; they contain only a few obscure vegetable remains, and are in all probability of freshwater origin. The sands and pipe-clays which at Studland Bay, Alum Bay, and Whitecliff Bay are seen immediately overlying the representatives of the

* Quart. Journ. Geol. Soc. vol. xviii. (1862) p. 65.
† *Ibid.* vol. iii. (1847) p. 354.
‡ *Ibid.* vol. xiii. (1857) p. 90.

London Clay were regarded by Mr. Prestwich as probably representing the Lower Bagshot of the London basin, and as being, like it, of freshwater origin *. The pipe-clays with abundant vegetable remains at Corfe, Branksea, Studland, and Alum Bay, all appear to be in this part of the Middle Eocene series. It is worthy of note that Mr. Prestwich confined the term Lower Bagshot beds to his stratum 5 of Whitecliff Bay, which he had previously called the "Lower Bracklesham Sands" †.

The Middle Bagshot of the London basin is only from 40 to 60 feet in thickness; it is of somewhat argillaceous composition, and of undoubted marine origin. So inconstant are its characters, however, in different parts of the London basin, that the line of demarcation between this and the other divisions of the Bagshot beds which was adopted by Mr. Prestwich, has evidently not been followed by the officers of the Geological Survey.

The Middle Bagshots contain only a few marine fossils: but these are sufficient to enable us to correlate them, without doubt, with the lower part of the Bracklesham series in the Hampshire basin. The Upper Bagshot of the London basin has a thickness varying from 100 to 150 feet, and only differs from the Middle Bagshot in its more purely arenaceous character, a distinction which is far from being constant. The Upper, like the Middle Bagshots, are of marine origin; but the fossils are exceedingly rare and very badly preserved.

With regard to the portions of the Hampshire Eocenes with which the Upper Bagshot of the London basin ought to be correlated, the greatest difference of opinion has prevailed. Mr. Prestwich's views are clearly stated in the following passage:—

"How far the Upper Bagshot Sands are related to the Bracklesham series it is difficult to say. The few fossils I have found in those sands are not sufficiently distinctive to enable me to pronounce a decided opinion. As, however, the fossiliferous Middle Bagshot Sands are very thin, and represent apparently only the lower or middle part of the Bracklesham series, I think it probable that it is the upper beds of sand and clay of the latter which pass northwards into the thick sands of the Upper Bagshot Sands. Still it is possible that part of them may represent the Barton series; for we see at Barton how shifting the upper part of that series is—how clay predominates at one place and sands at another" ‡.

In the various publications of the Geological Survey, however, the thin division of the Middle Bagshot is correlated without any expression of doubt with the whole of the Bracklesham and Barton series, a mass of strata which at Whitecliff Bay exceeds 700 feet in thickness, while a series of sands overlying the Barton Clay is regarded as the representative of the Upper Bagshot.

Mr. Gardner's studies of the beds in the Bournemouth area have led him to another, and much more probable, correlation of the Middle Eocenes of the Hampshire and London basins, a view which

* Quart. Journ. Geol. Soc. vol. iii. (1847) p. 395.
† *Ibid.* vol. xiii. (1857) p. 90, note.
‡ *Ibid.* vol. xiii. p. 132.

is much more in harmony with the conclusions of Mr. Prestwich as given in the paragraph cited above. Like the latter author, Mr. Gardner restricts the name of Lower Bagshot to the oldest part of the Middle Eocene, which immediately overlies the London Clay, and he finds a probable representative of the Middle Bagshot in his "Bournemouth Marine," and of the Upper Bagshot in his Boscombe Sand with its remarkable pebble-beds *.

In his memoir on the London basin, Mr. Whitaker admits that the grounds on which the classification of the Geological Survey is based are far from being satisfactory. As an explanation of the difficulties he feels, he suggests that the Barton Clay may be absent, and in this way the representative of a higher series of beds may come to rest on the strata of Lower-Bracklesham age †. But of the existence of any lacuna between the Upper and Middle Bagshots no evidence has ever been produced; and the difficulty experienced by Mr. Prestwich and the officers of the Geological Survey in fixing upon a clear line of demarcation between them seems to point to the conclusion that the one series graduates insensibly into the other.

Still more recently Mr. Herries has brought forward the evidence of some additional species of Mollusca, which he has found in the Upper Bagshot beds of the London basin, as throwing fresh light on the vexed question of their geological age ‡. These fossils are unfortunately all casts in ironstone, and it is admitted that their identification is in most cases very doubtful; nevertheless it is argued that the balance of evidence is in favour of associating the Upper Bagshot with the Barton rather than with the Bracklesham series. As there are, however, only three species said to be certainly recognizable, which are peculiar Barton forms (though one at least of these has certainly been found in the Bracklesham series), it must be admitted that the additional evidence is not of any very great weight. Mr. Herries, however, concludes from his study of this fauna that while the Upper Bagshot is the equivalent of the Barton Clay, "that part at least of the Hampshire-basin Upper Bagshot which at its summit, immediately under the freshwater Lower Headon at Hordwell, contains *Oliva Branderi* and *C.* (*Vicarya*) *concavum*, is a distinct and probably higher horizon" §. A still later paper on the subject by Mr. Tawney makes the same admission as to the imperfection of the evidence on which the "Upper Bagshot" of the London and Hampshire basins are placed on the same horizon. The author, however, argues in favour of the continued use of the term for the strata of the Hampshire basin, or, in other words, of applying the same name to two sets of strata of admittedly different age.

It will be seen from this review of opinion upon the subject that, while the general correlation of the beds of the Hampshire and Paris basins is undisputed, the exact age of the Bagshots of the London

* Quart. Journ. Geol. Soc. vol. xxxv. (1879) pp. 210, 227.
† Mem. Geol. Surv. Gt. Britain, vol. iv. pt. i. p. 333.
‡ Geol. Mag. new ser. dec. ii. vol. viii. p. 171.
§ *Loc. cit.* p. 173.

area is still a subject of much doubt; and this arises principally from the fact of the unfossiliferous character of these last-mentioned strata. According to the views of the officers of the Geological Survey, 660 feet of the beds seen at Alum Bay ought to be ranked as Lower Bagshot, while Mr. Gardner would restrict that name to 73 feet of those beds. What, if any such exist, are the Hampshire representatives of the Upper Bagshots of the London basin, is a question about which there is still greater and apparently hopeless divergence of opinion.

From this state of confusion into which the nomenclature of the Middle and Upper Eocenes of the Hampshire basin has unfortunately fallen, there is one and, as it appears to me, only one means of escape. It is clear that the Upper and Lower Bagshots of the London basin have not yielded a sufficient number of well-preserved organic remains to enable us to determine their exact place in the geological series. The naming of beds in the Hampshire basin, the age of which is clearly determinable, after these doubtful deposits, has been the source of an immense amount of confusion in the past. I would therefore advocate, as the only way of getting rid of this confusion, the total abandonment of the terms Upper and Lower Bagshot, as applied to strata in the Hampshire basin.

The beds in the Hampshire basin to which the term Lower Bagshot has been restricted by Mr. Prestwich and by Mr. Gardner, were formerly called "the Lower Bracklesham Sands" by the first-named author. This name appears liable to be misundersood, and has been withdrawn by its author. I would venture therefore to suggest as a convenient name for this series of beds, which is represented in Whitecliff Bay by Mr. Prestwich's bed 5, in Alum Bay by his beds 15 to 18, and on the Hampshire coast by the sands and pipe-clays of Poole, Corfe, Branksea Island, and Studland Bay, the term "Studland Series." The Studland beds are of purely freshwater origin; and they yield an abundant flora, which has now been shown to be perfectly distinct from that of the overlying Bournemouth beds *.

The Studland Series forms the lower part of the Middle Eocene in the Hampshire basin; and the upper part of that division is formed by the mass of strata which in its easterly development is purely marine but in its westerly development passes into brackish-water and freshwater deposits. The way in which this takes place has been admirably illustrated in the memoirs of Mr. Prestwich and Mr. Gardner. The marine type of this formation is the Bracklesham, the freshwater the Bournemouth series. Both the marine fauna and the terrestrial flora of these beds seem to be highly characteristic, so as to clearly distinguish it alike from the underlying and overlying deposits.

The Barton Clay, of which the limits, as defined by Mr. Prestwich, appear to me to agree much more closely with the continental classification than does the grouping proposed by Mr. O.

* Pal. Soc., British Eocene Flora, 1879, p. 16.

Fisher, is everywhere recognized as the representative of the Upper Eocene.

The series of sands immediately overlying the Barton Clay, and and called by the Geological Survey the "Upper Bagshot Sands," has long been known by the alternative name of the "Headon-Hill Sands;" and by this name, in order to avoid hopeless confusion, I would in the future propose to call it.

At Whitecliff Bay this series of sands is well exposed, forming a mass 200 feet in thickness, immediately overlying the representative of the Barton Clay. It is almost equally well seen at Headon Hill, where its thickness has been variously estimated at from 100 to 200 feet.

On the Hampshire coast these sands are exposed between Long-Mead End and Beacon Bunny, and again at Eaglehurst near Calshot, and they have been dug at many localities inland.

At Whitecliff Bay the sands in question are generally quite unfossiliferous; but the late Mr. Richard Gibbs, the excellent fossil-collector of the Geological Survey, found a band in which a number of ferruginous casts of shells were recognizable. These were too friable for removal; but Professor Edward Forbes examined them *in situ*, and recognized them as belonging to the marine genera *Cardium* *, *Panopœa*, and *Tellina*, and stated that so far as these forms were determinable they appeared to be identical with species found in the underlying Barton Clay.

At Headon Hill and at Eaglehurst, only comminuted and water-worn fragments of shells occur in these sands; but at Long-Mead End a band near the top of these sands contains a tolerably abundant fauna. The beds are evidently of brackish-water origin; for both marine and freshwater forms occur in considerable abundance in them.

These brackish-water Headon-Hill Sands, then, are intermediate in position between the marine Barton Clays below and the fresh-water Headon-Hill strata above. They represent the passage from marine to freshwater conditions; and that they are equally related to both these deposits is shown by the fact that Barton and Headon forms occur in them in about equal proportions †.

Above the Headon-Hill Sands we find at Whitecliff Bay a series of clays with bands of lignite attaining a thickness of about 40 feet. The fossils found in these beds appear to be entirely of

* Mem. Geol. Surv., The Geology of the Isle of Wight, 1862, p. 51: *Cardinia* here is clearly a misprint for *Cardium*.

† Mr. Tawney has recently stated that, of 28 species of shells found by him at Long-Mead End, only 21 per cent were Headon forms, while 35 per cent. were Barton forms. He therefore argues that the Headon-Hill Sands have closer affinities with the underlying Barton than with the overlying Headon Clays. But in a comparison of this kind every thing depends on the identification of species; and in some cases Mr. Tawney's identifications differ from my own, and, I believe, from those of other palæontologists both in England and on the continent.

The study of the fauna appears to me to show that the beds are almost exactly intermediate in age, as they are in position, between the Barton and the Headon Clays.

freshwater and terrestrial origin; and no brackish-water beds have been detected in this part of the series at Whitecliff Bay. But at Alum Bay, and at Hordwell Cliff on the opposite coast of Hampshire similar beds of clay and lignite occur attaining a greater thickness and containing bands with an admixture of freshwater and marine fossils, the latter almost always in a dwarfed condition. I will reserve what I have to say concerning the Headon Clays at Alum Bay, and proceed to point out the characters presented in the equivalent strata at Hordwell Cliff.

These strata at Hordwell Cliff have attracted much attention from geologists, owing to the rich harvest of mammalian and reptilian remains which they have yielded to the late Mr. Searles Wood, the Marchioness of Hastings, and other collectors. Many of the beds have received local names from fossil-collectors; and more or less detailed descriptions of the succession of the strata have been published by Webster, Lyell, Searles Wood, the Marchioness of Hastings, Dr. T. Wright, and the Rev. O. Fisher.

It is a remarkable fact, as pointed out by the late Edward Forbes *, that the published descriptions of these sections, though professing to give the most minute details, arrived at by measuring down the beds inch by inch, differ from one another in a very striking manner. My own observations on this section, carried on during the last twenty years, convince me that these strata, like most deposits of estuarine origin, are of the most inconstant character, varying in thickness within very short distances. Mr. Codrington estimates that this coast-line is receding, in consequence of the action of the sea, at the rate of a yard per annum; and he thus accounts for the remarkable discrepancies of different observers as to the thickness of the gravel †. Among such variable strata as these are, the section exposed to observers at different dates may vary considerably. I have in a previous paper pointed out the impossibility of relying upon the constancy of the thin beds of limestone, lignite, &c. in tracing the order of succession among these estuarine beds; but I think there can be no doubt as to the *general* succession of strata at Hordwell Cliff.

The Headon-Hill Sands, which at Beacon Cliff are much thinner than in the Isle of Wight, contain an admixture of freshwater and marine shells, and, as Mr. Searles Wood and Dr. Wright long ago pointed out, are of estuarine origin. The lowest bed of the overlying Headon-Clay series consists of green and blue laminated clays with much carbonaceous matter, occasionally passing into thin lignite seams. This bed, which is about $3\frac{1}{2}$ feet thick, is known locally as the "Lignite-bed." Above this Lignite-bed there is found a series of sands and sandy clays containing freshwater and terrestrial remains—plants, shells, and bones. From the fact that these beds, which are about twenty feet thick, have yielded to collectors the remains of *Paloplotherium*, *Palæotherium*, and *Dichodon*, they are known as the "Mammalia-bed." The top of this series is marked

* Quart. Journ. Geol. Soc. vol. ix. (1853) p. 268.
† *Ibid.* vol. xxvi. (1870) p. 532.

by a bed of dark-coloured clay about 2 feet thick, containing numerous impressions of leaves. Overlying this "Leaf-bed" is a series of white and grey sands with irregular bands of clay about fifteen feet thick. As this division yields many bones of *Crocodilus*, *Trionyx*, and *Emys*, it is well known, especially the upper part of it, to collectors, by whom it is called the "Crocodile-bed." About four feet higher we come to a thin, somewhat nodular band of marly limestone crowded with specimens of *Limnæa* and *Planorbis*. The thickness of this limestone varies, but may average about six inches. Above the limestone band we find a series of grey and green shelly marls and sands with occasional bands of lignite, measuring together about 20 feet. The total thickness of the beds so far described may be estimated at 65 feet.

Throughout this thickness of strata the fossils appear to be generally of freshwater and terrestrial origin. I have found some exceptions to this rule; for at three different horizons specimens of *Cerithium* occur, with other indications of the temporary coming in of brackish-water conditions. Resting on these strata, however, is the celebrated "Marine bed" of Hordwell, which has attracted such a considerable amount of attention from geologists.

Mr. Webster and Sir Charles Lyell, who published the first accounts of the Hordwell cliff, failed to find any trace of a marine formation there, although it is evident that their attention was particularly directed to the question of the existence of marine strata at this horizon. Both these authors, however, record the finding of specimens of *Cerithium* in fragments which had fallen from the cliff. But in 1840 Mr. F. Edwards detected a thin band containing numerous marine shells, which band he succeeded in tracing in the cliff for a distance of 300 yards. In 1843 Mr. Searles V. Wood, who examined the cliffs with great minuteness, could only trace this band for 100 yards; while in 1851 Dr. Wright only found it exposed at one place for a distance of about 10 yards. In 1853 the Marchioness of Hastings said that the bed was nearly worked out. Messrs. Keeping and Tawney thought that it had not been exposed for 28 years; but within the last twenty years, I have had the good fortune to find it on two occasions, though during numerous other visits I have altogether failed to do so.

Mr. Searles Wood estimated the thickness of this bed at only 9 or 10 inches, while Dr. Wright thought it a little more. The Rev. O. Fisher estimates it at 5 feet, but admits he had never seen the bed in section. I found myself that the marine shells were confined to a very thin band, certainly not more than a foot in thickness. Whether this thin seam has altogether disappeared through the wearing away of the cliff, as may well happen with such thin lenticular patches, or whether it is only concealed under the gravels and fallen detritus, I am not able to state; but the fact that the band could at one time be traced from the point where it rises on the shore to a place where it crops out in the cliff, and that I have frequently searched the place where it ought to occur

without success, leads me to entertain the view that the former supposition is the correct one *.

Above the "marine bed" at Hordwell there are seen about 20 feet of sands and marls with freshwater fossils. But, as Mr. Searles Wood pointed out long ago, the forms of Mollusca and Vertebrates occurring in these upper freshwater beds are precisely the same as those found in the beds underlying the "marine bed."

When these marine beds were first discovered, the whole of the fluvio-marine beds of the Hampshire basin were grouped according to Webster's classification into the Middle Freshwater, the Upper Marine, and the Upper Freshwater. The thin marine band of Hordwell was therefore at once claimed as the representative of the Middle Marine formation. The proofs brought forward by Prestwich and Forbes of the existence of a number of marine or brackish-water beds of different ages in the fluvio-marine series, while they have caused this classification to be abandoned in many points, do not seem to have altogether dispelled the old notions on the subject; for we find the Rev. O. Fisher still claiming this thin and inconstant band of Hordwell Cliff, which abounds with dwarfed marine shells mingled with freshwater forms, as the undoubted representative of the Middle or Marine Headon, the "*Venus*-bed" of collectors; and he even identifies the thin limestone band below it with the How-Ledge limestone of the Isle of Wight †.

But, as long ago pointed out by Mr. G. B. Sowerby, and admitted by Sedgwick and other observers, the division of the Headon beds into three series, the upper and lower of which are of freshwater, and the middle of marine origin, is one that will not bear the test of exact examination. All through the Headon series, bands containing some forms of marine mollusca, usually much dwarfed, occur; such brackish-water beds exist alike in the so-called Upper, Middle, and Lower Headon; and the utmost that can be said of these brackish-water beds, in which both marine and freshwater genera are mingled, is that they are perhaps most abundant in the central parts of the series. The so-called "marine band" of Hordwell is only one of the brackish-water intercalations of the Headon series.

The whole series of strata at Hordwell cliff is therefore as follows:—

	feet.
(1) Sands and marls with freshwater shells	12–20 seen.
(2) Sand with brackish-water shells ("Marine band")......	1 or less.
(3) Grey and green shelly marls and sand.....................	20
(4) Limnæan limestone..	$\frac{1}{2}$
(5) Green marls	4

* If the measures of the Marchioness of Hastings and Mr. Wise could be trusted, we must admit the existence of two marine bands in the Hordwell Cliff; for whereas these authors place their marine band 43 feet above the limestone bed, Dr. Wright reckons only 16 feet of strata between those two beds. My own measurements and those of the Rev. O. Fisher support the views of Dr. Wright as to the true place of the marine bed; Prof. Ed. Forbes (Quart. Journ. Geol. Soc. vol. ix. 1853, p. 268), however, thought the Marchioness of Hastings's section more reliable than that of Dr. Wright.

† Geol. Mag. new ser. dec. ii. vol. ix. (1882) p. 139.

		feet.
(6)	White sands and clays, with "Crocodile-bed" at top ...	15
(7)	Sandy bed with lignite ("Leaf-bed")	3
(8)	Greenish sands and clays ("Mammalian bed") with a band near the base containing estuarine fossils.........	20
(9)	"Lignite bed"	$3\frac{1}{2}$
(10)	Seam of sand crowded with estuarine shells ("*Oliva*-bed")	1
(11)	Sands with occasional brackish-water shells	30–40

These beds graduate so imperceptibly into the underlying Barton clays that it is difficult to fix the exact limits between them*.

As studied at Hordwell Cliff, then, the Headon sands and clays are seen to pass into one another by insensible gradations, they are both of estuarine origin, and they contain essentially the same fauna. What that fauna is, there is not the smallest room for doubt. The French geologists have long recognized at the top of their Grès de Beauchamp, which represents our Barton clay, a series of sands well exposed at Mortefontaine, Monneville, and even under Paris itself, containing a peculiar assemblage of fossils, and to which the name of the zone of *Cerithium concavum* has been given by Carl Mayer and Sandberger. Hébert, Carl Mayer, and many other foreign geologists have recognized in our Headon and Hordwell beds the representatives of the zone of *Cerithium concavum* of the continent. As in the continental beds, so in both the Headon sands and clays the very characteristic fossil *C. concavum* occurs in enormous abundance; and many other fossils are common to the English and French deposits. On the question of the position of this zone of *Cerithium concavum*, and the correlation of our Headon and Hordwell beds with them, all the most eminent Tertiary geologists of France, Germany, and Switzerland are perfectly agreed.

At Eaglehurst, near Calshot, variegated clays and sands with *Potamomya* and other freshwater shells are found overlying the representatives of the Headon-Hill sands just as at Hordwell. These clays are dug in the Solent brick-works; and by the aid of Mr. E. Westlake and Mr. Hooper I have been enabled to recognize among the bones found here remains of *Crocodilus Hastingsiæ* and of the well-known forms of *Trionyx* and *Emys* of Hordwell.

The Headon beds are 240 feet thick at Whitecliff Bay; at Alum Bay their thickness is variously estimated at from 300 to 400 feet; at Hordwell they exceed 120; while at Eaglehurst their thickness cannot be exactly determined.

The next series of strata exposed at Whitecliff Bay is the very interesting one for which I have proposed the name of the Brockenhurst series. The freshwater Headon clays are suddenly succeeded

* Mr. Searles V. Wood has obligingly furnished me with some notes which he made when working in company with his father at Hordwell in the years 1843 and 1845. He assures me that the whole of the vertebrate fossils obtained by his father, both reptilian and mammalian, were taken from the bed (6) which is called the "Crocodile-bed." Vertebrate fossils, however, appear to abound in both the divisions (6) and (8).

by a deposit of most unmistakably marine origin having a thickness of nearly 100 feet. So far as I have been able to discover, there is no appearance whatever of a gradual passage between these freshwater and marine series of beds, the lowest portion of the latter abounding in marine Mollusca, Bryozoa, and even Corals. The break between the Headon and Brockenhurst beds appears to be a complete one.

Messrs. Keeping and Tawney state that they found this marine series to lie upon an eroded surface of the underlying Headon beds*. This fact is in marked agreement with the sudden change in the nature of the fauna. At Roydon I have found an equally abrupt transition from the freshwater beds of the Headon to the marine ones of the Brockenhurst.

The lowest 15 feet of these beds, which are of an argillaceous character, contain the most numerous fossils; and these can be collected in great numbers at low water during spring tides. In the succeeding 45 feet of strata, which are of a sandy nature, marine fossils (and only marine fossils) are found, and such species as occur agree entirely with those found in the underlying argillaceous beds. The highest beds consist of sands and clays 40 feet in thickness, in which marine fossils become more numerous; at the top of the series there is an admixture of marine and freshwater forms, indicating a gradual passage into the overlying freshwater beds.

Now, with regard to the age of this marine series there is fortunately no room for doubt. There occurs in the New Forest a series of marine strata which Von Könen, Duncan, and after them many other authors have identified with the Tongrian of Belgium and the Lower Oligocene of Northern Germany. The identity of the fauna found in this marine series of Whitecliff Bay with that found in the New-Forest bed has been pointed out by the Rev. O. Fisher, Messrs. Codrington and Jenkins, and has been amply confirmed by the collections made by Messrs. Keeping and Tawney.

This continuous marine series of Whitecliff Bay Messrs. Keeping and Tawney propose to break up into four divisions. To the lowest two feet they give the name of "the Brockenhurst zone;" and the next 12 feet they call "the Roydon zone." These two divisions they unite to form the "Brockenhurst beds." The next division, "the *Sanguinolaria*-sand," 42 feet thick, they admit contains a number of distinctive Brockenhurst forms; but the highest division, 15 feet thick, they follow the Geological Survey in calling "the *Venus*-bed;" and the whole marine series, including the overlying 19 feet of sands, they group as the Middle Headon.

According to the view propounded by those authors the Brockenhurst zone is a thin, highly fossiliferous deposit, 2 feet thick at Whitecliff Bay, and varying from a few inches to a foot in thickness at the Brockenhurst cutting. Yet at Roydon brickyard, less than two miles away from Brockenhurst, this zone is stated to be altogether absent, nor could any trace of it be found at Hordwell, Headon, or

* Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 109.

Colwell Bay in the position which, according to these authors, it ought to occupy.

The "Roydon zone" has been established to include those portions of the Brockenhurst series in which certain fossils were thought to be absent or rare. My own collections, that of Mr. Edwards in the British Museum, and one made by Mr. E. Westlake and placed at my disposal, show that the strata at Roydon are much richer than Messrs. Keeping and Tawney appear to have concluded from their visit to the locality. Von Könen and Edwards had no doubt whatever of the contemporaneity of the Roydon and Brockenhurst beds; and the arguments by which it has been endeavoured to separate them are of the slightest character.

The identification of the overlying strata as "the *Venus*-bed," and its reference to the so-called Middle Headon are, I believe, equally unfounded. *Cytherea incrassata* (the "*Venus*" of collectors) is a species of wide range. It is said by the officers of the Geological Survey to have been found in the Barton Clay, though this is doubtful. All through the Headon series, however, from the top to the bottom, it makes its appearance wherever brackish-water or marine conditions occur. It equally abounds in the Brockenhurst beds and the Bembridge, a band crowded with examples of this shell overlying the Bembridge Limestone. Before the time of Edward Forbes this bed was unhesitatingly accepted as the "*Venus*-bed," the Bembridge Limestone being confounded with that of Headon Hill. In the marine Brockenhurst series of Whitecliff Bay, *Cytherea incrassata* occurs in great abundance in the bottom 15 feet; it is more sparingly scattered in the overlying 45 feet of sand, but again becomes very abundant in the overlying clays, its abundance or rarity being clearly determined by the nature of the sea-bottom at the time. Why one particular portion of the marine series should be singled out and called "*the Venus*-bed," I am quite at a loss to imagine. A considerable number of highly characteristic Brockenhurst forms, such as *Voluta spinosa*, *Strepsidura armata*, *Ostrea ventilabrum*, *Psammobia compressa* and *Cardita deltoidea*, occur in these upper beds, which at the top exhibit the gradual return to freshwater conditions by the presence of *Cyrena*, *Melania*, *Melanopsis*, &c.

But what is more fatal to the view that these beds belong to the Headon series, or zone of *Cerithium concavum*, is that the characteristic fossils of that horizon are wholly wanting in them. *Cerithia* (*C. pseudocinctum* &c.) abound in these beds; but, so far as my observations go, there is not a trace to be found of *C. concavum* and *C. ventricosum*.

The attempt to split up this series of marine strata into a number of distinct and widely distributed fossil-beds, is, I believe, an example of that misleading method which has already led to a considerable amount of confusion in the case of the Bracklesham series, as I have already pointed out in the earlier part of this paper.

Over the thickly gravel-covered area of the New Forest it is quite hopeless to attempt to follow the different divisions of the Eocene and Oligocene series. At one or two points, however, the marine

Brockenhurst series can be traced. In the banks of the stream called the Dark Water, near the village of Langley, and again in the sides of the Beaulieu river, just below the town of Beaulieu, the marine strata are exposed, where the great plateaux of gravel so well described by Mr. Codrington * have been cut through by the streams. At the latter of these localities a brickyard once existed, which has long since been closed and the pits filled in †. I have been able to collect in the river-banks the very characteristic *Voluta geminata* and other fossils of the Brockenhurst series. We meet with no further traces of them, however, till we come to the valley of the Lymington river, at Roydon and Brockenhurst and the localities in the immediate neighbourhood of Lyndhurst. We have no means of determining the total thickness of the Brockenhurst series in the New Forest; but at Roydon and near Lyndhurst it certainly exceeds 25 feet ‡.

III. *The Correlation of the Strata of Headon Hill and Colwell Bay.*

While the order of succession of the strata as seen in Whitecliff Bay at the eastern end of the Isle of Wight is clear and undisputed, such is far from being the case at Colwell Bay and Headon Hill, at the western end of the island: the strata containing the peculiar fauna of the Brockenhurst series appear, at first sight, to be entirely wanting at these localities; certainly no trace of such a formation can be detected in the position assigned to it by Messrs. Keeping and Tawney, namely at the base of the so-called "Middle Headon." If, then, we accept the interpretation of these authors, we must believe that while the Brockenhurst beds are well developed both at Whitecliff Bay and in the New Forest, they are wholly wanting at the intermediate localities.

But another explanation of the facts of the case has been suggested by M. von Könen and myself. The brackish-water beds of Colwell Bay yield a number of characteristic Brockenhurst fossils; and we have therefore been led to regard these Colwell-Bay beds as the brackish-water representatives of the Brockenhurst series, though we admit that in the New Forest they have a "richer and true marine fauna" §.

But it has been maintained that the brackish-water beds of Colwell Bay are clearly identical and continuous with the so-called Middle Headon of Headon Hill. On this point the greatest diversity of opinion has long existed. Prof. Hébert and Dr. Wright believed the brackish-water beds of Colwell Bay and Headon Hill respectively to be on different horizons; and Mr. G. B. Sowerby, Prof. Sedgwick, and Prof. Edward Forbes all admit that there are

* Quart. Journ. Geol. Soc. vol. xxvi. (1870) p. 528.

† An account of some of these New-Forest sections was given by Mr. J. C. Moore, Quart. Journ. Geol. Soc. vol. v. (1849) p. 315.

‡ Although the whole of the fluvio-marine beds of the New Forest are coloured by the Geological Survey as belonging to the Headon series, there can be little doubt that a considerable portion of them belongs to the Bembridge series.

§ Quart. Journ. Geol. Soc. vol. xx. (1864) p. 98.

considerable differences between these two sets of beds and the faunas which they contain.

The officers of the Geological Survey, it is true, treat these two sets of strata as being upon the same horizon ; but they at the same time maintain the identity of the Headon-Hill and How-Ledge limestones ; and nothing can be more certain than that, while the Colwell-Bay brackish-water beds *overlie* the How-Ledge limestone, the Headon-Hill brackish-water beds *underlie* the Headon-Hill limestones.

The great difficulty in arriving at a satisfactory conclusion concerning the order of succession of the strata at the west end of the Isle of Wight is due to the fact that, near the summit of the anticlinal in Totland Bay, there is an interruption in the sequence, owing to denudation, to the beds being covered up by later deposits, and possibly also to faulting. While a substantial agreement exists between the various detailed sections which have been published of the strata in Colwell Bay and Headon Hill respectively, the attempts to correlate these two sections have given rise to the greatest divergences of opinion.

Since the publication of my own attempt to explain the relations of these sections, several other memoirs have appeared dealing with the same question. Prof. Blake*, while differing from me on many points, expresses his dissent with perfect courtesy and fairness. Messrs. Keeping and Tawney have also published their interpretation of these sections †. The two sections recently published, though measured down bed by bed, differ in many important particulars from one another, from the sections of Mr. Prestwich, Dr. Wright, the Geological Survey, and from that published by myself. This arises, as I believe, from too great a reliance being placed upon the constancy of particular bands among these very variable estuarine deposits.

In dealing with the stratigraphical evidence, Messrs. Keeping and Tawney state that I have altogether misrepresented the position of the "Marine or Middle Headon." Any one who will refer to my former paper will at once see that the position which I assume is that of altogether denying the existence of any such group as the Middle or Marine Headon. Under the circumstances I may perhaps be forgiven for quoting what I actually did state on the subject. Speaking of the Headon group, I said "this group of freshwater and estuarine beds is more than 400 feet in thickness, and exhibits many indications of the prevalence from time to time of brackish-water and marine conditions;" and, again, "in all the lower part of the series we find a tendency to the recurrence of brackish-water conditions : and in these intercalated fluvio-marine bands we find numerous *Cerithia*, *Cyrenæ*, and dwarfed *Ostreæ*."

Precisely similar conclusions to those which I had arrived at were announced by Professor Sedgwick as the result of the careful study of the Headon-Hill strata, which he made with the assistance of Prof. Henslow. Professor Sedgwick states that "in Headon Hill the middle argillaceous group contains innumerable freshwater shells,

* Proc. Geol. Assoc. vol. vii. p. 151.

† Quart. Journ. Geol. Soc. vol. xxxvii. (1881) p. 85.

greatly predominating over the marine, and bands of lacustrine marl differing in no respect from that of the upper and lower groups "*.

That brackish-water shells occur in certain bands in the strata usually ranked as the Upper and Lower Headon, may be seen by an inspection of the sections of Dr. Wright, Prof. Prestwich, the Geological Survey, and Prof. Blake; and these brackish-water bands occasionally contain *Cytherea incrassata*. On the other hand the central portions of the Headon series contain so few purely marine forms, and such as do occur are in such a dwarfed condition, that Mr. G. B. Sowerby strongly insisted on the inaccuracy of styling it a marine formation; while Sedgwick, Forbes, and nearly all other observers have admitted that nowhere in Headon Hill do we find marine conditions so strongly marked as at Colwell Bay.

The fact is, as I have pointed out in my preceding paper, that the division of the Headon series into an Upper Freshwater, a Middle Marine, and a Lower Freshwater formation, is the last relic of a classification the inapplicability of which Sedgwick had begun to see in 1830, and which was rendered quite untenable by the subsequent discoveries of Prestwich and Forbes. The limits and divisions of this supposed Middle Marine Headon, as adopted by Messrs. Keeping and Tawney, are quite different from those given in the sections of the Geological Survey: and while the former authors include in it only from 31 to 33 feet of strata, Prof. Blake finds the brackish-water beds intercalated with about 45 feet of strata. A careful study of the published sections long ago convinced me that different authors had referred to different parts of the Headon group in describing the Marine or Middle Headon, and that no part of the series can be justly separated under that appellation.

The great difficulty which all authors have found is to correlate the strikingly different sections exposed in Headon Hill and Colwell Bay.

The method which was adopted by Dr. Wright, Mr. Bristow (in one of his sections †), and myself, was to select what appeared to be the most constant series of beds in the two sections, and to bring them into comparison.

All through Headon Hill there can be traced a great mass of sandstones and limestones having a united thickness of over 40 feet. It is true that, when examined in detail, this series of calcareo-arenaceous beds exhibits many variations; the thick masses of limestone which are seen at some points are at others broken up into several thinner ones by intervening sands or clays; and in some places the limestone contains fewer shells, and passes into a sandstone rock. But, in spite of its minor variations in composition, this mass of strata maintains its thickness and general characters for a distance of more than a mile, and forms the most conspicuous feature in the

* Proc. Geol. Soc. vol. ii. p. 294.

† The Tertiary Fluvio-marine formation of the Isle of Wight (1856), p. 132; The Geology of the Isle of Wight (1862), p. 62. In the table of Vertical Section No. 4, the difficulty in identifying the beds of Colwell Bay and Headon Hill has been attempted to be met in another way still.

mural face of Headon Hill. Only half a mile off, on the other side of the Totland-Bay anticlinal, a similar mass of sands and limestones appears in Warden Cliff, and, dipping below the sea-level, forms the dangerous reefs known as How Ledge and Warden Point, stretching away towards Hurst Castle. Indeed the lower part of this series can be traced continuously all through Totland Bay. It is true that in Warden Cliff the beds are generally of a more arenaceous character, and the limestone bands are thinner and in most cases more inconstant than at Headon Hill; but the series does not differ more at these two localities than it does in its course through Headon Hill, and the same species of freshwater Mollusca abound in both. Further, the Upper Limestone, that of How Ledge, is seen to greatly increase in thickness as we trace it in the direction of Headon Hill, and the sandy beds to become more calcareous.

Now, it has appeared to myself and other geologists that this well-marked mass of strata, which can certainly be traced without interruption through the whole of the Headon-Hill section, ought to be found in the Colwell-Bay section; but, according to the interpretation of Messrs. Keeping and Tawney, it there thins away to an insignificant nodular band not above 1 foot 4 inches thick *.

But if the Headon-Hill limestone series be identified with that of Warden Point, it is clear that the brackish-water beds of Colwell Bay overlying these limestones cannot be identical with those of Headon Hill, which underlie the limestones—a correlation which my critics so positively affirm.

The position which they take up is as follows:—Rejecting the identification of the beds at Warden Point and Headon Hill †, they proceed to indicate what they believe to be a surer means of correlation between the Colwell-Bay and Headon-Hill sections.

At the east end of Headon Hill, a little above Widdick Chine, the authors find a series of brackish-water beds, which they profess themselves to be able to identify, without the smallest possibility of error, with the well-known brackish-water beds of Colwell Bay. More than this, they assert that the series of beds at these two

* These authors (*loc. cit.* p. 90) have endeavoured to establish a curious *tu quoque* argument. They say that if they make a limestone 27 feet in thickness thin out to 1 foot 8 inches in a distance of 1 mile 926 yards, I have made the same bed thin out to 5 feet, and ultimately to 3 feet, in a distance of $1\frac{1}{6}$ mile. But in this, as in many other points, my critics have quite misunderstood my views; for I have not identified the How-Ledge limestone, but the whole mass of limestones and sands of Warden Point, with the similar series in Headon Hill.

† The officers of the Geological Survey have, in their memoir 'On the Tertiary Fluvio-marine Formation in the Isle of Wight' (p. 132), and in their general memoir 'On the Geology of the Isle of Wight' (p. 62), deliberately expressed their opinion that the correlation of the limestones at Warden Point and Headon Hill is the true one. Messrs. Keeping and Tawney state these repeated observations to be "an oversight or clerical error." Dr. Wright's equally distinct statement they in the same way characterize as "a mistake." The fact is, that the officers of the Geological Survey have expressed in their different writings three quite irreconcilable views. I have adopted one of these, Messrs. Keeping and Tawney another; but I am quite at a loss to understand the grounds on which these authors claim to be regarded as the defenders of legitimate authority.

points are not only in perfect agreement as to thickness and general characters, but that the numerous minor subdivisions at the one place are found exactly repeated at the other.

Let us examine these statements and the supposed proofs of them a little more closely. The distance between the point where the Colwell-Bay beds rise from the shore and that where their supposed representatives are seen at Headon Hill is $1\frac{1}{2}$ mile or 2640 yards. For a distance of about 1200 yards from Headon Hill to the Totland brickyard we have no trace of these brackish-water beds; but for the remaining 1440 yards they can be traced with occasional interruptions.

Near Bramble Chine, where the beds are exposed on the shore at low water, the Colwell-Bay brackish-water series is divisible into a number of local bands, which were well described by Dr. Wright, and may be distinguished by the names of the *Cerithium*-bed *, the Oyster-bed, the *Venus*-bed, the *Psammobia*-bed, and the *Neritina*-bed, the total thickness of these brackish-water beds being about 30 feet. These local divisions can be traced in the cliff for a short distance; but less than 300 yards away from the point where the beds rise on the shore, their characters are seen to undergo a total change; instead of the several distinct bands we have noticed, we find the brackish-water beds represented by a mass of dwarfed oysters between 20 and 30 feet thick. Tracing the beds in the cliff for a distance of another 350 yards, we find the characters of this so-called Marine or Middle Headon series undergoing another complete change: masses of light-brown and ferruginous sands come down to within 8 or 10 feet of the How-Ledge limestone; the brackish-water beds are reduced to a thickness of 5 or 6 feet only, and their fauna exhibits a much smaller admixture of marine forms: *Cerithia* and a few dwarfed *Ostreæ* occur, with great numbers of *Cyrenæ*; but many of the marine genera found in the exposures to the eastward appear to be here quite unrepresented. At Warden Point the brackish-water beds are now concealed; but in the tumbled cliffs on the other side of the point we again find their representatives †. A careful study of this part of the cliff shows that the marine and brackish-water shells are confined to several thin and inconstant bands. At a distance of less than 500 yards from the point where the brackish-water beds are lost in the cliffs, through denudation, we are able to trace their representatives in the Totland-Bay brickyard. This brickyard has been opened for a

* Messrs. Keeping and Tawney differ from previous observers in calling one of the forms of *Cerithium* which occur here *C. ventricosum*. The species is quite distinct from the shell known by that name in the zone of *C. concavum*.

† My original section, drawn on the true scale, both horizontal and vertical, when reduced to the size of a plate in the Quarterly Journal of the Society, was too small to allow of some of the relations of the beds being clearly shown. I therefore, for the sake of clearness, added a second section, in which the vertical scale was exaggerated. In this latter section the position of the Colwell Bay marine bed at Warden Point is clearly shown, as my critics admit; they nevertheless refuse to accept this section as illustrating my views, but severely criticise the other section for its want of clearness. In the same way they dwell at great length on some obvious printer's errors in the lists of fossils.

number of years; and I have had frequent opportunities of tracing the succession of beds exposed in it, which the Rev. O. Fisher and Mr. A. H. S. Lucas* rightly place on the horizon of the brackish-water beds of Colwell Bay and Warden Cliff. The strata exposed here are as follows:—At the top we find a mass of clays containing a few freshwater shells. These clays are more than 6 feet in thickness; and at their base is found a band containing dwarfed oysters and other brackish-water shells. *Cytherea incrassata* I have not found in this band, though it very probably may occur there. The brackish-water band, however, which is never more than 18 inches thick, is so inconstant that in parts of the pit which I have seen excavated it is found to thin out and disappear altogether; it is underlain by 10 or 12 feet of finely laminated white sands passing into sandy clays. In the foundation of a kiln these clays were seen to pass down into others crowded with *Potamomya* and other freshwater shells.

Now in Headon Hill, where these beds are next supposed to be seen, it is argued that we find the "Middle Marine" of Colwell Bay not only having the thickness, but exhibiting all the minor subdivisions exposed at the point where it rises from the shore, each little band with precisely the same series of fossils in it.

Between the two points compared, there is a distance of a mile and a half; for more than half this distance we can trace the series of beds at frequent intervals, and we find it undergoing four complete changes; and at the last place where it is seen it appears to be on the point of thinning out and disappearing altogether. Yet, in the next three quarters of a mile it is supposed to recover all its old characters, its original thickness, and even every minute subdivision is supposed to be recognizable in it!

The strata seen at Headon Hill, however, have in fact very little in common with those of Colwell Bay. In order to make a "Middle Marine series," a number of brackish-water beds have been grouped with a number of purely freshwater strata, including limestones crowded with *Limnæa, Planorbis*, and *Paludina*, and beds of lignite. In the one set of beds *Cerithium concavum* occurs in prodigious abundance, in the other it is exceedingly rare. The difference between the two series of beds compared was long ago pointed out by Mr. G. B. Sowerby, and has been admitted by Sedgwick, Forbes, and the officers of the Geological Survey. The one point which they have in common is an abundance of the conspicuous and showy *Cytherea incrassata*; and hence the local fossil-collectors call each of them a "*Venus*-bed."

My critics have collected about 50 species of fossils from both these beds, and state that they find them to be identical. But it is clear, from what is stated about certain species, that they differ, not only from myself, but from other English and continental palæontologists as to the identification of many forms of Mollusca. They have collected, too, only the shells of *the highest* brackish-water bands at Headon for comparison with those of the Colwell-Bay bed,

* Geol. Mag. dec. ii. vol. ix. (1882) pp. 102, 138.

while I have compared the whole of the Headon marine forms with those of Colwell Bay. Nearly 100 species are known and have been recorded by competent authorities from both of these localities.

I, on the contrary, find that the same genus is constantly represented by the different species at the two horizons, and, like Von Könen, I recognize a considerable proportion of the Colwell-Bay forms as identical with those of the Brockenhurst series.

At the same time, as both Von Köuen and I have admitted, the Colwell-Bay beds exhibit much more estuarine characters than do the strata at the New Forest localities. At Lyndhurst and Brockenhurst the beds appear to be truly marine, containing, as Dr. Duncan has shown, reef-forming corals; but at Roydon there occur a few specimens of *Cyrena* and *Melania*, which may have been washed in from a neighbouring river, while some of the most characteristically marine forms are absent or rare. At Colwell Bay, however, the admixture of freshwater with marine Mollusca becomes much more marked; many of the marine shells are dwarfed, while the corals and such genera of marine Mollusca as could not tolerate any admixture of fresh water are altogether absent. Further, as I have shown, the mass of brackish-water strata passes within a very short distance into a great oyster-bank; and this, when traced westward, is replaced by a number of thin brackish-water beds which at Totland-Bay brickyard appear on the point of thinning out and disappearing altogether*.

If the interpretation which I have advocated requires us to believe that the Brockenhurst beds, which at Colwell Bay begin to exhibit markedly estuarine characters, have, within less than two miles, thinned out altogether or passed into freshwater deposits, the theory opposed to it labours under still greater difficulties; for we are called upon by it to believe that the thick masses of the Headon-Hill limestones have almost entirely thinned out and disappeared at Colwell Bay. The Brockenhurst beds are said to form the base of the "Middle Headon;" and of this Middle Headon there are said to be clear sections at Headon Hill, Colwell Bay, and Hordwell. Has any one ever detected at any one of these localities a bed that can be regarded as this Brockenhurst bed? The whole of the Headon beds, both sands and clays, abound with *Cerithium concavum* and its varieties. *Cerithia* occur in considerable abundance in the Brockenhurst beds; but *Cerithium concavum* is absent from

* I have stated, in my paper and section, that the places where the Colwell-Bay marine bed, if it be continuous, should occur in Headon Hill are concealed by gravel and landslips. My critics declare that at one particular point there is no gravel, and take great exception to my description. They state that only "local taluses" occur. I can only ask any one who has taken the footpath from the keeper's lodge to Headon Cottage, to judge if my statement is not strictly correct. The thinness and inconstancy of the brackish-water bed at Totland Bay brickyard points to the conclusion that it is on the point of dying out altogether. Mr. Gardner has obligingly furnished me with some sections he had made by digging at the east end of Headon Hill, which seem to show that the Brockenhurst marine band has entirely disappeared. But, as Mr. Prestwich's section long ago showed, traces of brackish-water beds are found on this horizon at the other end of the hill.

these beds at all the typical localities*. Quite apart from the evidence afforded by the equivalent strata of the Continent as to the relative positions of the beds which contain the Brockenhurst fauna and those belonging to the zone of *Cerithium concavum*, it seems to me that the theory of Messrs. Keeping and Tawney labours under insuperable difficulties.

If the Colwell-Bay estuarine strata be not the fluvio-marine representatives of the Brockenhurst series, then it must be maintained that the last-mentioned series, which is so well represented both at Whitecliff Bay and in the New Forest, has altogether thinned out and disappeared from the sections of the west end of the Isle of Wight, or that the marine beds are represented by others of purely freshwater character. This appears to be the view adopted by Messrs. Keeping and Tawney. I believe, however, that the interpretation which I have given is the one which best accords with the facts of the case; and it has the additional merit of bringing our own series of strata into perfect harmony with the succession made out by the labours of continental observers with respect to the equivalent deposits in France, Belgium, and Northern Germany.

IV. *Conclusion.*

The Lower Tongrian, as is well known, has no marine representative in the Paris basin, the great freshwater gypseous series occurring on this horizon; but in the small basin of the Cotentin, as M. G. Dollfus has so well shown, the Lower Tongrian or Brockenhurst series is represented by the "argile à Corbules"†.

The Headon series, including both the sands and overlying clays, contains a fauna which, by Hébert, Sandberger, Mayer, and other authors, has been recognized under the name of the zone of *Cerithium concavum*. The Brockenhurst series contains a fauna which has been quite as universally recognized as agreeing with that of the continental Tongrian or Lower Oligocene.

Now, if my interpretation of the section be the true one, the beds containing the Tongrian fauna in the Hampshire basin overlie those containing the fauna of the zone of *Cerithium concavum*; and this is the relation which is believed to exist between their continental representatives. Most geologists, indeed, group the zone of *Cerithium concavum* with the Upper Eocene or Bartonian, and the representatives of our Brockenhurst series with the Lower Oligocene.

But, according to the views of Messrs. Keeping and Tawney, the beds which in this country contain the Lower Oligocene fauna

* I have pointed out that the several geological horizons in the Oligocene are characterized by different forms of *Cerithium*, just as different zones in the Mesozoic rocks are characterized by different species of *Ammonites*. My critics take the same exception to my views as has been urged by those who oppose the zonal classification of the Jurassic rocks: they assert that *C. concavum* is occasionally found at higher horizons than the zone of *C. concavum*. While *C. concavum* occurs in prodigious abundance in the Headon clays and sands, it is exceedingly rare at Colwell Bay, and altogether absent at Whitecliff Bay and the New Forest localities.

† Mém. Soc. Géol. de Normandie, 1880, p. 510.

form a thin and very inconstant bed in the midst of the strata containing the fossils of the zone of *Cerithium concavum*.

At Whitecliff Bay, where the order of succession is clearly exhibited, the brackish-water bands containing the fossils of the zone of *Cerithium concavum* are absent, but the Brockenhurst beds are well displayed and of considerable thickness. At Headon Hill the zone of *Cerithium concavum* is well seen, but the Brockenhurst beds seem to be altogether wanting. At Colwell Bay there occurs a series of beds which I take to be the estuarine representative of the Brockenhurst series, but which my critics declare to be only the zone of *Cerithium concavum* with a somewhat more marine character.

However this subsidiary question may be settled, I do not believe that the main facts of the correlation which I advocate are in any danger of being impaired. My critics have altogether failed to show that, at any point in the Hampshire basin, beds containing the characteristic fauna of the zone of *Cerithium concavum* overlie beds containing the Brockenhurst fauna; and on the Continent the latter are always superimposed upon the former. My critics hold that between the New Forest localities and those at the west end of the Isle of Wight the Brockenhurst beds have thinned away or passed into freshwater deposits; my contention is, that they appear in an estuarine form at Colwell Bay, and thin out or graduate into freshwater deposits between that place and Headon Hill.

In conclusion, I must point out that the vexed question of the order of succession of the beds at Colwell Bay and Headon Hill has only an indirect bearing on that of the position and correlation of the Oligocene strata of the Hampshire basin, which it was the main object of my paper to establish. If my interpretation be the correct one, then we have here, as I pointed out in my previous paper, an additional confirmation of the succession so clearly established by the study of the Whitecliff-Bay section. But if, on the other hand, the views advocated by Messrs. Keeping and Tawney be adopted, it adds no support to their views as to the position of the Brockenhurst beds; for these authors admit that nothing like the Brockenhurst beds can be detected either in the Colwell-Bay or Headon-Hill section.

I still firmly maintain the necessity of separating these beds from the Upper Eocene, with which they are usually grouped by English authors. The Hempstead series of the Isle of Wight is the undoubted representative of the Fontainebleau sandstones, a formation which no continental geologist would think of grouping in the Eocene. Either with Lyell and Hébert we must place the Hempstead beds in the Lower Miocene, or we must admit the term Oligocene as a convenient and now well-recognized name for these deposits which are intermediate in age between the Eocene and Miocene. Nothing could possibly be more detrimental to the progress of geological science than to attempt to perpetuate the use of the term Eocene in a sense quite distinct from that in which it is employed by all other geologists, alike in France, Belgium, Germany, Switzerland, and Italy.

DISCUSSION.

Prof. PRESTWICH said he had listened with great interest to the paper concerning this most difficult subject. Over the whole area only two zones were well marked, that of the London and that of the Barton Clay. The Bracklesham beds, on the other hand, were clear in the Whitecliff section, but were not indicated by fossils in the Alum-Bay sections. Further west still, about Poole, Bournemouth, &c., the beds became still more sandy, and more difficult of correlation. So, again, in the London basin, where, perhaps, we had nothing above the Bracklesham series. In all the fluvio-marine series there were great variations. Still he felt some difficulty in accepting the explanation offered by Prof. Judd. One thing was that the author failed to point out on the same horizon in Headon Hill any marine beds corresponding with the Colwell-Bay beds. At the same time he admitted that the variation of the beds rendered identification very difficult.

Mr. J. STARKIE GARDNER said that Mr. Monckton, in the neighbourhood of Wellington College, had got good Bracklesham forms in the green beds, and in the white sands above had found true Barton forms. He asked why the beds marked 20 in the section were classified with the Headon. He had recently trenched on Headon Hill from the Bembridge Limestone to the Upper Headon limestone, but had found no fluviomarine deposits.

Mr. TAWNEY said that he would not delay over matters of classification; for the question of the adoption or not of the term Oligocene was one that it might be hoped would be settled by the International Congress of Geology. Among all the beds exposed in the section exhibited at Whitecliff Bay he would only refer to those between the Upper Bagshot Sands and the Osborne series. With regard to his late paper in the Proceedings of the Cambridge Philosophical Society, the point raised was that the fossils of the said sands at Hordwell allied them to the Barton beds more nearly than to the Headon. So far as he understood Prof. Judd's communication, it was a reiteration of his former paper; and as no new facts were adduced, he would answer with no new arguments, and must apologize for repeating what has already appeared in the 'Journal' of the Society. He had shown, like previous observers, that the Brockenhurst fossils only occurred at the base of the Middle Headon; both at Whitecliff Bay and in the New Forest they lie immediately on the freshwater Lower Headon. He had not made four new series, but three zones were discriminated as subdivisions of the Middle Headon at Whitecliff. The characteristic Brockenhurst fossils did not pass up into the upper zone at Whitecliff; nor did they occur at all at Colwell Bay, the Brockenhurst zone being entirely absent there. Above the Middle Headon at Whitecliff came the freshwater Upper Headon, precisely as in the New Forest, Colwell Bay, and Headon Hill, and then the Osborne beds. These series were easily identifiable by their fossils.

Passing to the wset end of the Isle of Wight, he must repeat that

it has been shown that *Cerithium concavum* occurred at Colwell Bay; and in all its other fossils the marine bed there was identical with the Middle Headon of Headon Hill, and which was no "superstition." Touching the physical evidence, the Colwell-Bay bed could be followed with the eye as absolutely continuous up to Weston Chine; it was therefore waste of time to talk of the variations of this bed in Colwell Bay as proving any thing; the only place where it was not perfectly continuous was between Weston and Widdick Chines; but the beds below, viz. the Warden sands and certain *Chara*-beds, could be shown to be continuous; and so the series was continued on into that of Headon Hill without any difficulty. He considered it a very elementary problem in geology. It has been previously shown that Prof. Judd has misplaced the position of the *C. concavum* beds under Heatherwood Cottage, and has added over 100 feet here by counting part of the series twice. Moreover, if the Colwell-Bay bed existed higher up in Headon Hill, as Prof. Judd stated, it ought to be found; but in the position indicated quite other and freshwater beds existed. The speaker maintained all that had been printed in the paper referred to, and felt convinced that the orthodox view was correct.

Mr. Bott asked what came in between the two series. The argument of the alteration cut both ways. The beds, after changing for a while, might return to their former condition.

Mr. Keeping said that the correlation of the Bracklesham beds at Whitecliff Bay, Stubbington, and Selsea Bill was certainly correct, and in the New Forest probably so. There could be no doubt about the correlation of the Middle Headon beds at Hordwell, Colwell Bay, and Whitecliff Bay. The zone of *Voluta geminata* was some 20 feet thick above the Brockenhurst zone. He regarded the Upper Headon as a truly lacustrine series, never having found any marine fossils in it; nor had he done so in the Lower; but in the Middle Headon freshwater forms were mixed with marine. He thought that the Geological Survey would be found to be correct in their reading.

Mr. Watts said that he had searched very carefully above the Upper Headon limestone, and had found no marine beds, and could more readily understand that the former bed had thinned rather than that the Middle Headon group of the latter character should have disappeared.

Prof. Judd was glad to find that Prof. Prestwich agreed with him as to the variability of the fluvio-marine series, and also as to the main facts of the classification of the Oligocene strata. As regarded one point remarked on, viz. the absence of the Colwell-Bay marine bed in Headon Hill, he had indicated that by the time it had reached Totland-Bay brickyard it had become reduced as a marine band to a bed not 18 inches thick. These brackish-water bands thinned out very rapidly. Hence it was very probable that the bed had died out before reaching Headon Hill. As regards the *Cerithia*, he had not been able in Whitecliff Bay to find *C. concavum* in the series he had called Brockenhurst. His opponents rested their case on the identity

of zones of fossils in Colwell Bay and Headon Hill; but he had shown that these beds when traced towards Totland Bay varied greatly. It was vain to talk of the work of Prof. Forbes. No one respected Edward Forbes more than he did; but many facts were before us now which were not before that most eminent geologist. If Messrs. Tawney and Keeping were right, the foreign geologists were wrong. He, however, inclined to think that it was possible to interpret the English section so as to agree with their reading.

46. *On* Organic Remains *from the* Upper Permian Strata *of* Kargalinsk, *in* Eastern Russia. By W. H. Twelvetrees, Esq., F.L.S., F.G.S. (Read June 21, 1882.)

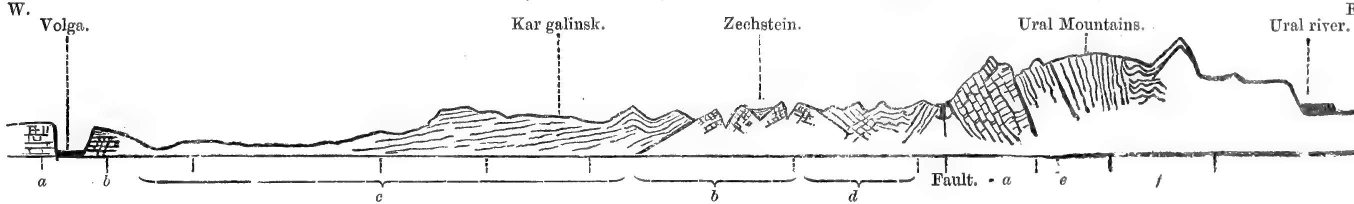
[Plates XX., XXI.]

The cupriferous sandstones composing the Kargalinsk steppe, or steppe of Kargala, to the N. of Orenburg, lie out of the ordinary track of travellers, but offer an interesting field for research. The railway now takes us as far as the town of Orenburg, whence a drive of thirty or forty miles leads into the heart of the important mining district to which I now propose to invite your attention. The doubts thrown on the Permian age of these strata in the discussion upon my former paper induce me to submit a few remarks bearing upon the question.

The country is a grassy, treeless, undulating steppe, covered superficially with the well-known black earth, or tchernozem, considered by Murchison to be of marine origin. The balance of evidence, however, is in favour of it being a vegetable mould. Sluggish meandering streams intersect the steppe. The exposures of the subsoil on the banks of streams and ravines show nothing beyond red marl or sandstone devoid of fossils. The mine-borings and shafts cut down through red, yellow, and grey sandstones, and red and white marls, fossiliferous wherever the beds of copper ore exist.

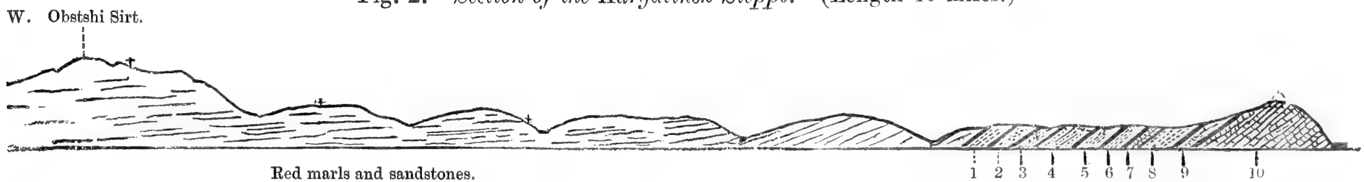
The key to the geological horizon of these mines is found by travelling in an easterly direction. We need not go so far as the Carboniferous Limestone and Upper Grits of the same system, which form the western edge of the crystalline rocks of the Urals; nor is it necessary to traverse the ninety miles of Lower Permian conglomerates and sandstones forming the hilly country between the Carboniferous and Magnesian Limestone outcrops (fig. 1). On the eastern border of the Kargalinsk steppe there are two protrusions of limestone with *Terebratula elongata*, *Loxonema*, &c., which throw off the Kargala cupriferous sands east and west. The most westerly of these two anticlinals, divided at Jeemangoolova by the post-road from Orenburg to Ufa, sinks to the west under the main mass of the strata of Kargalinsk, and does not appear again on this parallel. A reference to Murchison's map will show that this limestone outcrop runs roughly N.W. and S.E.; and I do not believe that there is much, if any, Upper Permian behind it. About fifteen miles further south it is well exposed near Sakmarsk, a Cossack town twenty-five versts from Orenburg. It here appears in several peaks or elevations, the principal of which are known as the Great and Little Grebeni. The Grebeni limestone is plentifully charged with characteristic Permian fossils, viz.:—

Fig. 1.—*General Section from the Volga to the Ural.* (Length about 400 miles.)



a. Carboniferous.
b. Zechstein.
c. Upper Permian.
d. Lower Permian.
e. Devonian.
f. Silurian.

Fig. 2.—*Section of the Kargalinsk Steppe.* (Length 40 miles.)



1, 2, 4. Dark Red Sandstones.
3. Red Sandstone with some Limestone.
5. Red Sandstone with clay breccia.
6. Hard Sandstone.
7. Grey limestone, slightly cupriferous.
8. Red Sandstone.
9. Yellow Sandstone, flaggy.
10. Zechstein.

Schizodus rossicus.	Fenestella retiformis.
Cyathocrinus ramosus.	Avicula sericea.
Nautilus Freieslebeni.	Strophalosia horrescens.
Clidophorus Pallasi.	Murchisonia, sp.
Avicula speluncaria.	Arca, sp.
Spirifera alata ?	Terebratula elongata.
Loxonema, sp.	Gervillia ceratophaga, *Schl.*
Productus ?	

A thin band of marl lies immediately below this limestone and upon barren red sandstone of the Lower Permian. This band may be taken as the equivalent of the Kupferschiefer. It contains a few fossils undistinguishable from some in the limestone, viz. *Terebratula elongata*, *Schizodus rossicus*, *Clidophorus Pallasi*, *Arca*, and a few obscure vegetable remains; it is slightly cupriferous.

The limestone again appears to the west of Orenburg. The Majak quarries, four versts N.W. of the town, show it dipping at a gentle angle, and appearing to pass under Orenburg, which would then be on Upper Permian. The thick terraces of red sandstone and clay exposed on the high bank of the river Ural, upon which the town is built, are unfossiliferous. A boring made in the town in 1841 registered alternate beds of red and grey sandstones and red clay or marl to a depth of 1366 feet. It is difficult to explain the absence of the Zechstein limestone in this boring upon any other hypothesis than that of its inconstancy. It is just possible, however, that the whole series belongs to the Lower Permian.

Further north the limestone hills appear at Bikoolova, Kitayam, &c. At Slonofka and Jemati (near Darghina) its bedding is nearly horizontal. It runs presumably under the superincumbent sands as far west as Samara, on the Volga, where it forms the cliffs of that river and of the Samara stream. From these cliffs I obtained *Loxonema*, sp., and *Pleurotomaria*, sp.

The wide-spread upper sandstones (fig. 2) rest in apparent conformity upon the Zechstein limestone, which in the places just named, and at other spots further N.W., is revealed by upheaval or laid bare by denudation. Fig. 3 is a vertical section, taken from no particular spot, but typical of the whole.

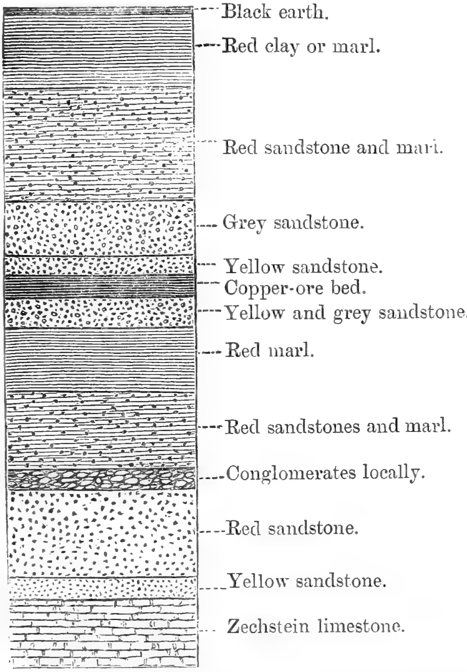
Although the reappearance of the Zechstein limestone at Samara would indicate its continuity beneath the intermediate part of the basin, yet further north it loses its monad character, and alternates with marls, which are variable and inconstant on the same horizon and in the same district; at the same time the limestone itself assumes a less calcareous and more earthy aspect. Without caution, mistaken opinions may be formed as to beds being above or below the limestone, when in reality they may be intercalated; but at Kargalinsk there is more uniformity in the principal divisions of the system. When we leave the limestone behind us we do not find it again.

The preceding remarks are not intended as a sketch of the geology of the country, but are simply such preliminary observations

as seem necessary to a general knowledge of the district whence the fossils cited hereafter have been derived *.

It will be desirable to take note of the labours of others. The earliest writer I can discover is Kutorga, who in 1838, in his 'Beitrag zur Kenntniss der organischen Ueberreste des Kupfersandsteins am westlichen Abhange des Urals,' described some plant-remains from the Permian steppe to the north of Kargala, as well as reptilian teeth and humeri, assumed by him to be mammalian, from undetermined localities in the governments of Orenburg and Perm.

Fig. 3.—*Diagram Vertical Section of the Upper Permians of Kargalinsk.*



In 1840 and 1842, Wangenheim von Qualen transmitted remains to Moscow from the steppe north of Kargala, which were noticed by Fischer de Waldheim in the 'Bulletins' of the Imperial Society of Naturalists of Moscow for those years.

In 1842 and 1844 Kutorga described some more of Qualen's fossils from the Bielebee steppe. His two papers are entitled "Beitrag," and "2ter Beitrag zur Palæontologie Russlands," and

* Mr. Thos. Rickard is preparing a detailed description of the geology of the district, which I hope he will intrust to me to communicate to the Society.

appeared in the 'Proceedings' of the Imperial Mineralogical Society at St. Petersburg for the two years named.

In 1842 Wangenheim von Qualen contributed a paper to the 'Proceedings' of the same Society, on the geological characters of the government of Orenburg, in which he maintained that the infra-conglomerate sandstone of the Klutchefsky mine, fifty versts south-west of Sterlitamak, which furnished *Rhopalodon Wangenheimi* and other Saurian remains, is Zechstein and Kupferschiefer. This is an erroneous conclusion; for the Klutchefsky sandstones are superior to the Magnesian Limestone. I have nowhere found or traced *Rhopalodon*, or any other reptilian remains in Russia, below the Upper Permian series of sandstones.

In 1843, the same author wrote* a more detailed memoir on the stratigraphy of the western part of the government of Orenburg, adopting a tripartite division of the Permian system here:—1. The lower group of limestones, cupriferous marls, and sandstones; in this he included the Klutchefskoi beds, which, as just mentioned, really belong to the Upper Permian series; 2. A middle group of marls, sandstones, and limestone with zechstein fossils; 3. A thin upper series of tufaceous limestone and white marls. The errors involved in the classification of the lower group have been widely circulated; and any light which can be thrown upon the question will be useful.

In 1844 he again wrote on the copper ores of the Orenburg government †. He was a zealous field-geologist, and his descriptions are full of interest to those acquainted with the districts he describes; but it would be hazardous to accept his judgment upon any crucial question of stratigraphy or palæontological classification.

In 1841 Count Keyserling writes (Bull. Soc. Mosc. 1841, p. 894):—"The examination of this great red formation is, on account of want of fossils, extremely difficult: great trunks of trees are the only petrefaction which we have received from it."

In 1845 Sir Roderick Murchison, in the 'Geology of Russia and the Ural Mountains,' described the Permian system of Russia, and noticed this region in particular. He paid a visit to the Kargalinsk mines, as appears from the following remarks in the work just alluded to (vol. i. p. 148):—

"In following this section a little to the west, the next succeeding beds are found to be composed of red siliceous conglomerate, slightly dipping off at first, but soon becoming horizontal, in which copper ore being largely disseminated has given rise to the mines of Kargalinsk. As in other places where copper ore abounds, fossil trees and plants are also of frequent occurrence; and although at the time of our visit we were not so fortunate as to procure them, this spot has also afforded many remains of fishes (*Palæonisci*), with bones of Saurians" &c.

In 1848 Eichwald wrote a memoir, "Ueber die Saurier des kupferführenden Zechsteins Russlands," viz. *Rhopalodon*, *Deuterosaurus*

* Verhandl. min. Ges. St. Petersb. 1843, pp. 1–58.
† Ibid. 1844, pp. 31–61.

and *Zygosaurus*. This appeared in the Moscow Society's Bulletin for that year (Part ii. pp. 136–202).

In the same year Wangenheim von Qualen wrote a further paper, "Beiträge und Ergänzungen zu den geologischen Verhältnissen des Orenburgischen Gouvernements," &c. (See the Moscow Bulletin 1848, Part ii. pp. 372–441).

In 1862 he wrote "Einige Bemerkungen über die geologischen Beobachtungen in Russland insbesondere im Ural von R. Ludwig," in which he contests Ludwig's statement of the existence of Trias in Northern and Central Russia. (See Mosc. Bull. 1862, Part i. pp. 608–627.)

In 1864 he again wrote on Marcou's 'Dyas et Trias (en Russie),' deprecating that author's description of the cupriferous marls and sandstones of Orenburg and Bielebee as Bunter. (See Mosc. Bull. 1864, Part i. pp. 172–189.)

Ludwig, in 'Geinitz's Dyas,' describes the Russian Permian at some length. Speaking of the Kargalinsk sandstones (vol. i. p. 300), he suggests that "it is not clear, from Murchison's description, whether the cupriferous-sand ores of Kargalinsk, in which silicified wood, plant-impressions, *Palæoniscus*, and bones of Saurians are found, belong to the Rothliegende or to the beds which, at Nijni Troitsk, overlie the Upper Zechstein." Referring to the Russian Permian as a whole, he says (p. 304) "the upper fluviatile or lacustrine group, with *Uniones*, plants, and bones of Saurians, must in the interim be placed somewhere between the Palæozoic and Mesozoic formations, or as comparable with the Vogesen-Sandstone of Sulzbach."

Göppert describes some of the plant-remains in his 'Fossil Flora of the Permian system.'

The difficulty of correlating the organic remains with Permian forms of Western Europe consists in the circumstance that for the most part they are specifically distinct, and in some cases generically so. The latest and most complete list I have been able to verify is as follows:—

Cardiopteris Kutorgæ, *Trautsch*,= Aroides crassispatha, *Kut.*
Walchia biarmica (*Eichw.*).
Walchia piniformis, *Sternb.*
Lepidodendron.
Schizodendron tuberculatum, *Eichw.*
Anomorrhœa Fischeri, *Eichw.*
Caulopteris?
Calamites infractus, *Gutb.*
—— Sückowi, *Brongn.*
—— gigas, *Brongn.*
Calamites leioderma, *Gutb.*
Unio umbonatus, *Fisch.*
Platyops Rickardi, *Tw.*, a Labyrinthodont.
Rhopalodon Wangenheimii, *Fisch.*, Cliorhizodon orenburgensis, *Tw.*, Deuterosaurus, } Theriodonts.
Various labyrinthodont and reptilian remains.

As regards the flora the list has a Palæozoic aspect, but a Secondary one as respects the reptilian remains. It may be that the snrvival of the older and more persistent forms should count for less than the appearance of the new ones. On the other hand the genetic history of the reptilia may need pushing back a stage further in time.

Cardiopteris Kutorgæ, Trautschold, = *Aroides crassispatha*, Kutorga.

Kutorga, in 1838, attributed these leaves to an Aroid plant. Eichwald (Leth. Ross. i. p. 253, tab. xiii. figs. 1, 3, tab. xvii. fig. 2) referred the bud to *Nœggerathia Gœpperti*, "gemma ovalis e foliis convolutis ovatis flabellatim nervosis composita." Göppert (Foss. Flora d. perm. Format. pp. 154, 157, tab. lxii. figs. 1, 2) thought the bud belonged to the Musaceæ, and the leaf to *Nœggerathia*. Dr. Trautschold has pointed out to me that the reference to Musaceæ cannot be correct, as a midrib is not present.

Schimper (Traité de Pal. Vég. tome ii. p. 130) says that an isolated leaf given him by Eichwald recalls certain leaves of the genus *Pycnophyllum*, Brongn. The venation of *Pycnophyllum*, however, is much finer and closer, besides being parallel. Further on (p. 506) Schimper treats *Aroides crassispatha*, Kut., as synonymous with *Palæospathe aroidea*, Ung., "spatha ovato-lanceolata, marginibus convolutis, coriacea, longitudinaliter striata, tres pollices longa (Ung. Gen. et Spec. 334)", and locates these leaves under floral organs, although with a certain degree of hesitation; for he says (p. 505) "les organes foliaires problématiques réunis dans ce genre ressemblent assez aux spathes de certaines Monocotylédonées, surtout des Palmiers, pour leur être comparés."

Recently Dr. Trautschold (Bull. Mosc. 1881, Part ii. pp. 122–124) has determined it as a *Cardiopteris*, and given it the specific name *Kutorgæ*. It is true that in the venation and appearance of the leaf it agrees with that genus; but surely the imbricated bud does not accord with the circinate vernation of ferns. Trautschold's figures are admirable representations of the leaf. A very interesting circumstance connected with the occurrence of this leaf is that it is also found in the Lower Permian sandstone in the forest of Voskresensk, about 2 miles west of that village.

Schizodendron tuberculatum, Eichwald, Leth. Ross. p. 266, pl. xviii. fig. 10. Plate XX. fig. 1.

This was treated by Eichwald as a Monocotyledon. Schimper cites Eichwald's genera *Stigmatodendron*, *Angiodendron*, and *Schizodendron*, under *Tylodendron*, Weiss, as "truncus incertæ sedis" belonging to the Coniferæ (tome iii. p. 576). Göppert (Foss. Flora, p. 139) compares this species with certain decorticated forms of *Lepidodendron*. I think it may prove to be a Lepidodendroid or Sigillarian root. The medulla has disappeared, and its place is occupied by sandstone: and none but extremely slight traces of any ligneous zone are observable. Exteriorly (on one side) are longitudinal ribs and furrows, the former mounted with tubercles. Fragments of a gnarled epidermal layer are preserved, but do not exhibit any areolæ as in *Stigmaria*, nor do the projecting tubercles present the central raised ball shown in *Halonia*. Deprived of the epidermis, the root is ribbed and furrowed pretty regularly. I have seen a piece of *Lepidodendron* from these mines; but, unfortunately, it is now out of reach.

The tubercles of this specimen are more numerous as the termination is approached, favouring the idea of rootlets issuing from those points, though I cannot say whether these tubercles had their seat only in the epidermis or were continuous with the ligneous cylinder and medullæ.

Eichwald's specimen was from the Cupriferous Sandstone near Bielebee, doubtless the same horizon as that of Kargalinsk.

WALCHIA BIARMICA (Eichw.), Schimper, 'Traité de Paléontologie végétale,' 1870–72, tome ii. p. 239. Plate XXI. fig. 3.

In 1844 Kutorga described ("Zweiter Beitrag zur Paläontologie Russlands," in the Verhandlungen der Russ. kais. min. Gesellsch. zu St. Petersburg, pp. 65–66, t. i. figs. 1–4) some twigs from the Kargalinsk mines, which he attributed to *Voltzia brevifolia*, Brongn. Brongniart, however, in a letter to De Verneuil (Geol. Russia, vol. ii. pp. 503, 504), was of opinion that Kutorga's figure rather resembled twigs of *Walchia*, and that at any rate the specimens were too imperfect to be placed with certainty in the genus *Voltzia*.

Eichwald, in his Leth. Rossica (p. 229, pl. xix. figs. 2 & 3, 1855–1861), also repudiated Kutorga's determination, and described the twigs as *Ullmannia biarmica* and *U. Bronnii*. The specimen I here submit is identical with his *U. biarmica*; even the appendages which he calls bracts or flowers are present. He states the locality as near Kargala, in the Bielebee district, while Kutorga gives it as the Kargala mine, in the Orenburg district,—a further instance of the confusion constantly occurring between these two places.

Geinitz, in his 'Leitpflanzen des Rothliegenden u. des Zechsteingebirges oder der permischen Formation in Sachsen,' 1858, p. 23 (and in his 'Dyas,' vol. i. p. 156), includes Kutorga's *Voltzia brevifolia* among the synonyms of *Ullmannia selaginoides*, Brongn.

The next mention I find of the Orenburg species is in a paper by Dr. Ch. Ernst Weiss, of Saarbrücken, entitled "Ueber *Voltzia* und andere Pflanzen des bunten Sandsteins zwischen der untern Saar u. dem Rheine," where he cites its locality, among others, as needing verification, and recommends examination by those who have facilities for doing so.

Göppert, in 1864–65 ('Palæontographica,' "Die fossile Flora der permischen Formation") remarks that Kutorga's figures 1–3 could refer just as well to a species of *Walchia*; only fig. 4 reminds one of *Voltzia*. As for *Ullmannia biarmica*, Göppert considers it more related to *Walchia* than *Ullmannia*, and is strengthened in his opinion by an original example received from Wangenheim von Qualen.

The latest opinion, and the one I adopt, is by Schimper (*op. cit.* p. 239), who treats Eichwald's *Ullmannia biarmica* as a *Walchia*, viz. *W. biarmica*. At the same time I may mention that I have seen in the collection of the Mining Institute, St. Petersburg, an undoubted *Ullmannia* from the Orenburg or Bielebee Permian.

The presence of a midrib in the leaves may be inferred from the specimen now exhibited; and some faint markings indicate parallel venation. This mainly influences me in rejecting the *Voltzia* determination.

Walchia piniformis, Sternberg, Fl. d Vorw. i. p. 22. Plate XXI. figs. 4, 5.

Walchia foliosa, Eichwald, Leth. Ross. i. p. 235 t. xix. f. 1.

These twigs are of common occurrence in the ore. They are found not so frequently in the sandstone as in the laminated marls, in which thin layers are almost entirely made up of vegetable remains in a confused state. It is not, I believe, a case of growth and decay *in situ*, but seems to be rather the result of drifting on some lake- or river-shore of the plants growing not far distant. Large coniferous trunks met with in the ore-beds are, I am informed, always rootless and branchless, and lie with their axes in the direction of the ore-stream. The inference is that they are drift timber.

Eichwald cites *Walchia lycopodioides* (Brongn.) and *Walchia foliosa* from the Orenburg Permian; but, with the inexactness which often confronts us in his writings on this district, as well as in those of Kutorga and Wangenheim von Qualen, he gives the habitat of the latter plant as "dans le grès cuivreux, groupe inférieur du Zechstein dans le gouvernement d'Orenbourg." All the Orenburg *Walchia* specimens which I have seen have been derived from the upper marls and sandstones. Eichwald regarded his *W. foliosa* as a small annual (!); but Schimper and Göppert speak doubtfully of the determination.

Dr. Trautschold (Bull. Moscou, 1880, iii. p. 124) would prefer to call it *Lycopodites foliosus*, considering the flexible stems and leaves as agreeing more with the Lycopodiaceæ than the Coniferæ.

I have specimens showing a considerable amount of flexibility, and others very rigid and straight; but as there are intermediate forms, I do not venture to separate the two extremes. As for the separation of *W. foliosa* from *W. piniformis*, I am not in possession of sufficient material for guiding me; and, so far as I can see, Eichwald was in the same predicament.

Anomorrhœa Fischeri, Eichwald, Leth. Ross. vol. i. p. 102, pl. iv. figs. 3–4.

This is classed by Schimper among the ferns, and as perhaps not different from *Chelepteris*, Corda. Eichwald's specimen was derived from the Klutchefskoi mine; and I have seen one from the mines of Kargalinsk.

Calamites infractus, Gutbier. Plate XX. fig. 2.

This is the most common species. A young stem figured by Geinitz (Dyas, pl. xxv. fig. 4.) corresponds very well with many specimens from this district. Eichwald's *C. arenaceus* (pl. xiv. fig. 1.) is nothing other than *C. infractus*. According to Fischer (Bull. Mosc. 1847, xx. p. 513.) a Calamite derived from the Ivanoffsky mine belonged to *Cal. arenarius*, Brongn. No figure is given, and possibly it was the present species. The specimens in the Museum of the Mining Institute in St. Petersburg identical with mine are labelled *C. infractus*. It is singular that Murchison did not come across it on his visit to the Kargalinsk mines, as its fragments are less difficult to find than those of any of the other species.

CALAMITES LEIODERMA, Gutbier. Plate XXI. fig. 1.

The ribs are somewhat broader than in Gutbier's type; but the length of internode and apparently thin texture suggest (somewhat doubtfully) that it may be the same.

CALAMITES SUCKOWII, Brongniart. Plate XX. fig. 3.

This is not abundant at Kargalinsk, yet by no means rare.

Other Calamites quoted from the Orenburg Permian are *C. columella*, Kutorga (West-Ural cupriferous sandstone), *C. Sternbergii*, Eichwald (cupriferous sandstone of Kargala, in Orenburg government), *C.* (*Equisetites*) *gradatus*, Eichwald (Klutchefskoi mine, district of Bielebee), *C.* (*Equisetites*) *distans*, Eichwald (Kargala), *C.* (*Equisetites*) *decoratus*, Eichwald (locality doubtful), and *C. gigas*, Brongniart (from the Permian cupriferous sandstone of Pyskorsk, Orenburg). I have seen a specimen of *C. gigas* from Kargalinsk, but have not been able to verify the other species.

UNIO CASTOR, Eichwald, Leth. Ross. p. 1003, pl. xxxix. f. 20.

UNIO UMBONATUS, Fischer, De Vern. Geol. Russ. vol. ii. p. 306, pl. xix. f. 10. Plate XXI. figs. 7, 8.

Some confusion exists with respect to these shells. Eichwald dissents from De Verneuil's determination, and at page 1002 of his work, pl. xxxix. f. 21, describes a different form as *Unio umbonatus*, assuring us that his drawing is from the original specimen of Fischer. Eichwald's *U. umbonatus* is identical with an unnamed *Unio* described and figured by Kutorga*, and stated by him to occur as casts of very varying size, in a bluish-grey marl, in which Wangenheim v. Qualen says *Palæoniscus Tscheffkini*, Fischer, is found. Eichwald gives the locality of *U. umbonatus* as the clay of the cupriferous sandstone of Kargala in the government of Orenburg. Whether this is the Permian of the Kargala in the Bielebee district, or of the Kargala near the town of Orenburg, is not clear. I have not seen his shell in the Kargalinsk mining-centre.

Unio castor, described by Eichwald (p. 1003) as occurring in the clay schists of the Magnesian Limestone of Bourakova, in the government of Kazan, associated with Cyprinidæ and *Posidonomya*, is the sole form of mollusk found in the Kargalinsk mines, and is, in places, very abundant.

With a view to extricate the shell from the confusion of its double name, I applied to Dr. Trautschold; and he replied to me as follows:—"If Eichwald, as he says, prepared his drawing from Fischer's original specimen, of course his *Unio umbonatus* is the genuine one, and De Verneuil would be in error. De Verneuil says that he shares Fischer's opinion respecting the location of the shell in the genus *Unio*; but he does not state whether Fischer saw his *Unio*. To be sure, Eichwald is not very trustworthy; but it is now probably impossible to prove whether his drawing was really made after Fischer's original or not."

* "Beitrag zur Paläontologie Russlands," Verhandl. d. mineral. Gesell. zu St. Petersburg, 1842, p. 27, pl. vi. f. 4.

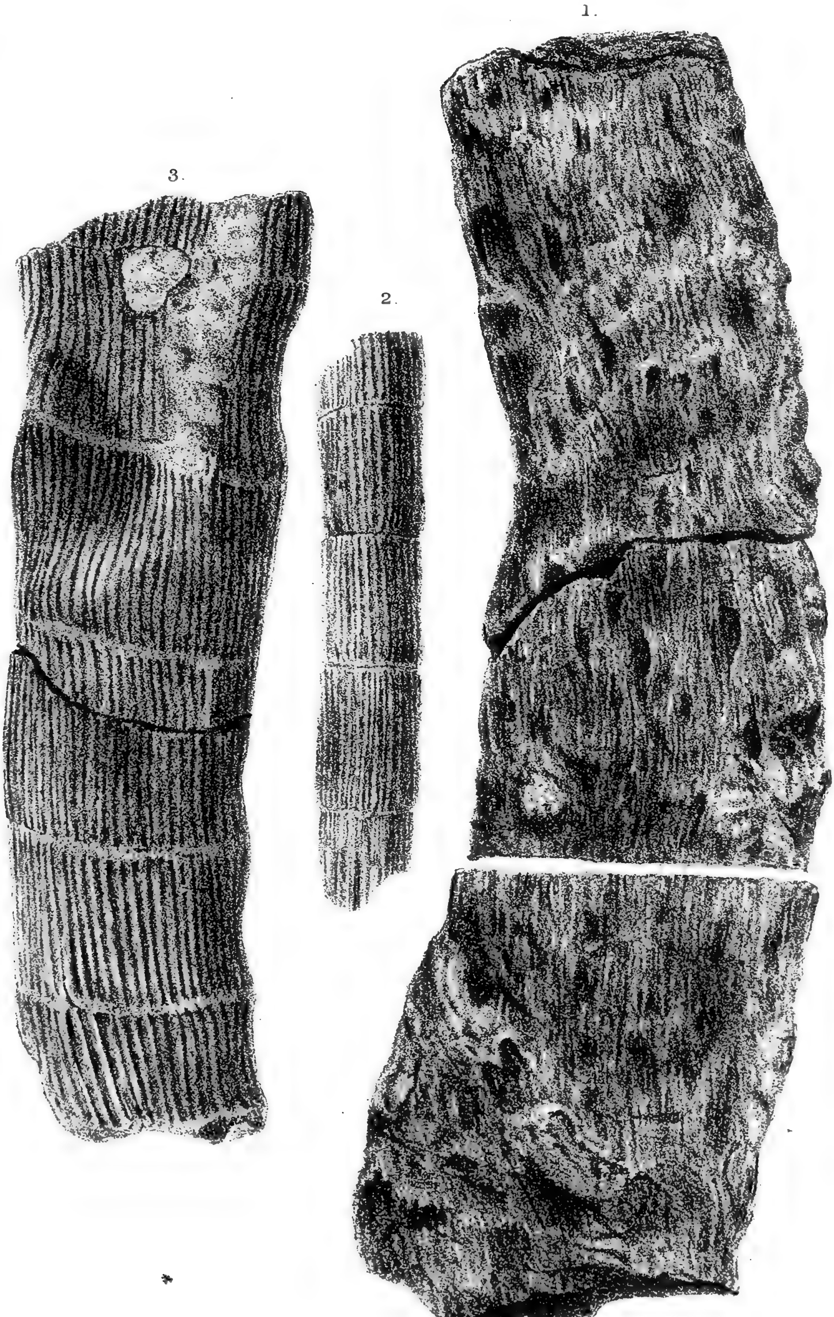
The question is therefore left where I found it. Being merely a matter of nomenclature, it is comparatively unimportant.

When Mr. Rickard and I were travelling together in the government of Simbirsk in the summer of 1879, we saw hanging in the public library of the town of Simbirsk, on the Volga, a geological chart entitled "Jasikoff's Table of the Rocks of the Government of Simbirsk, published by the Imperial Mineralogical Society of St. Petersburg." In this *aperçu* of the relations of the rocks of Simbirsk and neighbouring governments the Trias was represented as occurring in the government of Orenburg (Ufa), on the banks of the rivers Sheshma, Koochooa, Zaee and Igenee, in the form of variegated sandstones of a thickness approximately estimated at 200 feet, and containing the following fossils—*Cypris Pyrrhæ*, Eichwald, *Mytilus castor*, Eichwald, *Convallarites erecta*, Brongn., *Pterophyllum*, *Neuropteris*, *Cyclopteris*, *Calamites*.

Mytilus castor can be no other than our Kargalinsk *Unio castor* (= *U. umbonatus*): and this would seem to indicate that Jasikoff's Triassic series is on the same horizon. On the other hand *Convallarites erecta* = *Schizoneura paradox*, Schimper, Traité de Paléontologie végétale, tome i. p. 282, pl. xiv., is a plant the branches and leaves of which occur in the Bunter sandstone of the Vosges ("dans le grès bigarré supérieur des Vosges," Schimp. p. 282). I have never seen or heard of it from the Kargalinsk series, and, having regard to the many infelicities in determination for which the early describers of fossil remains from this field are responsible, I dare say no more than that the alleged discovery requires corroboration. Jasikoff has been dead many years: and I believe his Triassic theory has not gained much support in Russia.

Fish-remains are found sometimes in the marls, but mostly as fragmentary impressions. Genera which I have positively identified are *Palæoniscus*, *Amblypterus*, and *Platysomus* in true heterocercal forms.

Teeth and bones of Labyrinthodonts occur but rarely in a state satisfactory enough for description. The same may be said of the reptilian remains. Parts of jaws and teeth of *Rhopalodon*, Fischer, and *Deuterosaurus*, Eichwald, and humeri with entepicondylar foramina occur from time to time. The characters of these remains are those of Owen's order Theriodontia. Whether such characters are really ordinal or merely of family value is, I take it, still *sub judice*. The value of the arguments *pro* and *contra* depends largely on individual estimate of what constitutes ordinal characters. I think Cope's work in America will, when completed, greatly assist us in our conclusions respecting Theriodonts. However, these Kargalinsk remains betoken reptiles of a high grade, and are especially interesting as coming from Permian rocks; for, whatever may be thought about the upper rocks further west, where perhaps there is (though not demonstrated) a passage upwards into the Trias, these remains are in beds well down in the sandstone series. If Triassic fossils are to be looked for in the Kargalinsk district, they should be sought at Droojeloobny, high up on the Obstschi Sirt, where horizontal beds



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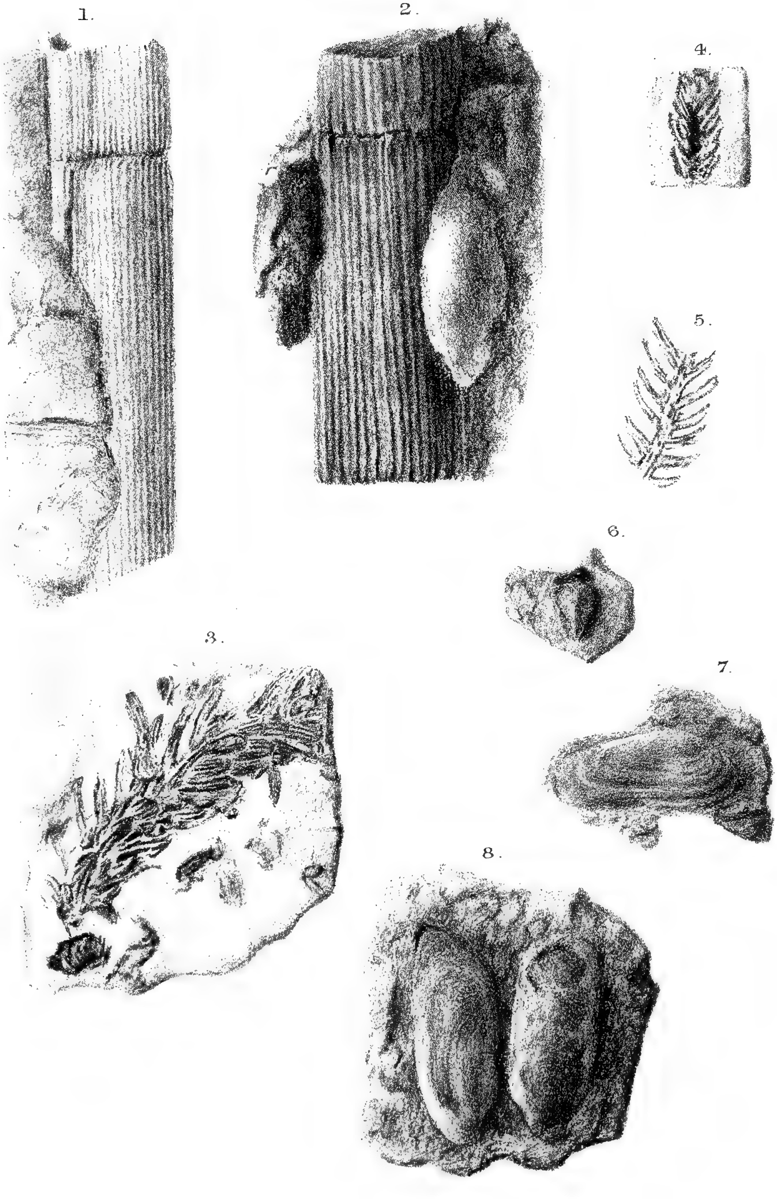
KARGALINSK FOSSILS.



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KARGALINSK FOSSILS

several hundred feet above the easterly mines indicate the removal by denudation of a corresponding thickness from the Roshdestvensky and Pravy mines, the undoubted homes of these highly organized reptiles.

After considering all the facts I have been able to glean by personal inspection and from all sources of information known to me, I imagine that possibly some of the beds in the central part of what is known as the Permian basin may be passage-beds between the Permian and Trias, but that the series of Kargalinsk forms the uppermost beds of the Permian as here developed. I know it is often impossible to draw the line between the two systems; but at Kargalinsk I draw it over the beds containing *Calamites gigas*, *infractus*, and *Suckowii*, *Cardiopteris Kutorgæ*, *Walchia piniformis*, *Unio umbonatus*, and the heterocercal fishes. We may be puzzled by the appearance of the higher forms of the cold-blooded vertebrates; but the lower types of life are surely more reliable witnesses. Regarding the whole subject as worthy of the attention of English geologists, I have thought it advisable to lay the facts before the Society and leave them for interpretation.

EXPLANATION OF THE PLATES.

Plate XX.

Fig. 1. *Schizodendron tuberculatum*, Eichwald.
2. *Calamites infractus*, Gutbier, typical specimen.
3. *Calamites Suckowii*, Brongniart.

Plate XXI.

Fig. 1. *Calamites leoiderma*, Gutbier.
2. *Calamites* undetermined.
3. Twig of *Walchia biarmica* (Eichwald).
4, 5. Twigs of *Walchia piniformis*, Sternberg.
6. Seed of a conifer.
7, 8. *Unio umbonatus*, Fischer.

Discussion.

Prof. Hughes asked if the Permian of Russia passed up unconformably and without any break into those beds which the author described as the passage-beds between Permian and Trias.

Rev. A. Irving said the Permian and Trias of Germany were stratigraphically conformable as well as those of Russia. He thought there was more than one Magnesian Limestone in the Russian Permians.

The Author, in reply to Prof. Hughes, stated that there is no positive evidence of the existence of Trias in the district. The Upper and Lower Permian were clearly distinguished by certain features; and he did not agree with the opinion that there was a repetition of Magnesian Limestones.

47. *On* Chilostomatous Bryozoa *from* Bairnsdale (Gippsland). By Arthur William Waters, Esq., F.G.S. (Read June 21, 1882.)

[Plate XXII.]

The present communication must be considered a continuation of my papers on South-west Victorian Chilostomatous Bryozoa (Quart. Journ. Geol. Soc. vol. xxxvii. p. 309) and "On Chilostomatous Bryozoa from Mount Gambier" (Quart. Journ. Geol. Soc. xxxviii. p. 257). The collection was lent me by Mr. J. R. Y. Goldstein, who, I presume, collected them himself from Bairnsdale; and it contains several very interesting specimens, though, in consequence of the other two collections of the same age being first described, the number of species not previously known fossil from Australia is only 14 out of a total of 42.

There are several species now found in the *Eschara*-form which are known in other places incrusting; and I must point out that the number of incrusting species in this collection is very small, though possibly this may depend to a certain extent on the circumstances under which they were collected. Those who have followed these three papers on the Australian Bryozoa will have noticed in how many cases the same species is now known in different modes of growth: sometimes, as in *Membranipora macrostoma*, *Cribrilina terminata*, *Mucronella mucronata*, *Porina coronata*, *Porina larvalis*, *Lepralia foliacea*, *Microporella elevata*, and *Smittia reticulata*, the same species is found in these fossil beds in more than one form; in other cases we find species only previously known with different colonial growth—for instance, *Membranipora cylindriformis* (?), *M. appendiculata*, *Steganoporella perforata*, *Cribrilina monoceros*, *Porina larvalis*, *Smittia seriata*, *Schizoporella auriculata*, *Smittia anceps*, and *Mucronella nitida*; while the two stages of living forms are known in *Steganoporella magnilabris*, *Lepralia foliacea*, *Porella concinna*, and *Smittia reticulata*. We have also seen a *Catenicella* in a new and interesting form, besides *Crisia* without joints.

If the old classification had not previously been discarded, the present collections would by themselves have shown the necessity of using zoœcial before zoarial characters.

We have now from the three localities 127 determined species of Chilostomata, of which 52 are known living and 41 fossil; 14 are considered identical with European Miocene species, 17 with Pliocene, and 4 are thought to be identical with Cretaceous species.

Having completed the description of the Chilostomata, I propose next to deal with the Cyclostomata from the three localities in one communication.

List of Species.

	Page.	Living.	S.W. Victoria.	Mt. Gambier.	Orakei Bay.	Localities.
1. Cellaria malvinensis, *Busk*	503	*	*	*		
2. —— angustiloba, *Busk*..............	504	...	...	*	*	
3. Caberea grandis, *Hincks*	504	*	*	*		
4. Membranipora appendiculata, *Rss.*	504	*	...	...	...	Miocene & Oligocene.
5. —— cylindriformis, *Waters*.........	504	...	*	*		
6. —— macrostoma, *Rss*...............	504	...	*	*	*	
7. Steganoporella Rozieri, *Aud.*, var. indica, *Hincks*	505	*	...	...	...	Miocene.
8. —— perforata, *MacG.*, var. clausa	505	?				
9. —— magnilabris, *Busk*	506	*	*	*	...	Miocene.
10. Cribrilina terminata, *Waters*	507	...	*			
11. —— monoceros, *Busk* (non *Reuss*)	507	*				
12. Mucronella mucronata, *Sm.*.........	507	*	*	*		
13. —— nitida, *Verrill*	507	*	...	...	...	Crag.
14. Microporella ciliata, *Pall.*, var. ...	508	*				
15. —— elevata, *T. Woods.*	508	...	*	*		
16. —— decorata, *Rss.*	508	*				
17. —— yarraensis, *Waters*	508	*	*	*		
18. —— violacea, *Johnst.*	508	*				
19. Porina coronata, *Rss.*	508	*	*	*	*	
20. —— larvalis, *MacG.*	509	*	...	*		
21. Lepralia depressa, *Busk*, var.	509					
22. —— burlingtoniensis, *Waters*......	509	...	...	*		
23. —— bairnsdalei	509					
24. —— gippslandii	509					
25. —— foliacea, *Ell. & Sol.*	509	*	*	*		
26. Porella denticulata, *Stol.*...........	510	...	*			
27. Smittia Tatei, *T. Woods*	510	...	*	*		
28. —— reticulata, *MacG.*..............	510	*	...	*		
29. —— anceps, *MacG.*.................	510	*	*			
30. Schizoporella phymatopora, *Rss.*...	510	...	*			
31. —— auriculata, *Hass.*..............	511	*	...	*		
32. —— acuminata, *Hincks*	511	*	...	*		
33. —— bombycina, *Waters*	511	...	...	*		
34. —— ventricosa, *Hasw.*..............	511	*	*			
35. Palmicellaria Skenei, *Ell. & Sol.*...	511	*				
36. Retepora marsupiata, *Sm.*	511	*	*	*		
37. —— rimata, *Waters*.................	511	...	*	*		
38. —— deserta	511					
39. Cellepora yarraensis, *Waters*	512	...	*	*		
40. —— albicans, *Hincks*	512	*				
41. —— pumicosa, *Busk*	512	*				
42. Lunulites cancellatus, *Busk*.........	512	*	*	*		

1. CELLARIA MALVINENSIS, Busk.

Loc. Living and fossil, from S.W. Victoria and Mt. Gambier.

2. Cellaria angustiloba, Busk.

Melicerita angustiloba, Busk, Quart. Journ. Geol. Soc. xvi. p. 261.

Cellaria angustiloba, Waters, "Chil. Bry. Mt. Gamb." Quart. Journ. Geol. Soc. vol. xxxviii. p. 260, pl. ix. figs. 28–30.

Loc. Fossil: Mt. Gambier, Orakei Bay (*Stol.*), Muddy-Creek beds.

3. Caberea grandis, Hincks.

For synonyms see "Chil. Bry. Mt. Gambier," Quart. Journ. Geol. Soc. vol. xxxviii. p. 261.

Loc. Living: Curtis Island (*H.*). Fossil: S.W. Vict., Mt. Gambier.

4. Membranipora appendiculata, Reuss. Plate XXII. figs. 2, 3, 4, 5.

Cellepora appendiculata, Rss. Foss. Polyp. d. Wien. Tert. p. 96, pl. xi. fig. 22.

Membranipora appendiculata, Rss. Die foss. Bry. des öst.-ung. Mioc. p. 41, pl. ix. figs. 13–16.

Membranipora cyclops, Busk, Mar. Poly. p. 61, pl. lxv. fig. 3.

Zoarium in *Eschara*-form. Zoœcia large, ovate, surrounded by a very thick raised margin; the area is much depressed, with a large aperture, which is rounded on the distal end, widening below, with almost straight sides and the proximal edge straight. There seems to have been a spine on one side. Immediately below the aperture a short, broad avicularium directed downwards. Aperture 0·41 millim. wide.

The zoœcia are usually arranged in parallel series with great regularity.

This is very similar in form to some cells of *Membranipora trifolium*, S. Wood—as, for example, Crag Polyz. pl. iii. fig. 9; but that is a much smaller species, the aperture only measuring 0·15 millim. Two distinct species of *Membranipora* seem to have been described from the Crag under the name *trifolium*. *M. appendiculata* also resembles *Eschara propinqua*, Hag., which is common in the Chalk of Maestricht; but the aperture in that species is also smaller, only measuring 0·25 millim., and has no avicularia. The cells in the specimen described by Reuss are somewhat larger than in those from Bairnsdale.

Loc. Fossil: Miocene, Mödling, Eisenstadt, Miechowitz; Upper Oligocene, Astrupp and Bünde; Middle Oligocene, Söllingen. Living: New Zealand (B.).

5. Membranipora cylindriformis, Waters.

For synonyms see "Chil. Bry. S.W. Victoria and Mount Gambier," Quart. Journ. Geol. Soc. vol. xxxvii. p. 323, & vol. xxxviii. p. 263.

Loc. Fossil: S.W. Victoria, Mount Gambier.

6. Membranipora macrostoma, Reuss.

For synonyms see Quart. Journ. Geol. Soc. vol. xxxvii. p. 323, & vol. xxxviii. p. 262.

From Bairnsdale, in the *Eschara*-form. This may be the same

as *M. loxopora*, Rss. In the Bairnsdale specimen the avicularia above the aperture are often very large, occupying nearly the space of a zoœcium. They are then broad and directed laterally.

7. STEGANOPORELLA ROZIERI, Aud., var. INDICA, Hincks.

Steganoporella Rozieri, Hincks, " Gen. Hist. of the Mar. Polyzoa," Ann. & Mag. Nat. Hist. ser. 5, vol. vi. 1880, p. 379, pl. xvi. figs. 1, 1*a*.

Eschara ignobilis, Reuss, " Foram. Anth. & Bry. des Septarienthones," Denkschr. Ak. Wissensch. Wien, xxv. p. 65, pl. vi. fig. 14.

Vincularia novæ-hollandiæ, Haswell, " On some Polyzoa from the Queensland Coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. 1, p. 41, pl. iii. fig. 3.

Vincularia steganoporides, Goldstein, Bry. from Marion Islands, 1881, p. 6, pl. ii. fig. 5.

Zoarium in *Eschara*-form. The shape of the avicularia cannot be made out; but there are large oval avicularian openings in the lower part of the zoœcium, and in one case there is an irregular triangular opening apparently caused by the coalition of two avicularia. I have a *Steganoporella* from the Miocene of Brendola (N. Italy) which has very similar cells, but with a tubercle on each side of the mouth; but in that case there is a large cell about the length of three and the width of two zoœcia.

Loc. Living: India (*Hincks*), Marion Islands (*Gold.*), Holborn Islands (*Haswell*), Darnley Islands, Torres Straits (*in my coll.*),—in the last three places in the *Vincularia*-form. Miocene: Söllingen.

8. STEGANOPORELLA PERFORATA, MacG., var. CLAUSA, nov.

Membranipora perforata, MacG. Zool. of Vict. decade iii. p. 29, pl. xxv. fig. 2; decade iv. pl. xxxvi. fig. 3.

Zoarium in *Eschara*-form. The zoœcia are irregularly hexagonal to ovate, and are much larger than those of *Steganoporella Rozieri*, Aud., with very narrow borders, the rims of the zoœcia keeping quite distinct although close together. Instead of there being large open pores below the mouth, these are closed by a calcareous covering the centre of which is mamillated and perhaps perforated. In the Bryozoa the membranous structures are often replaced by calcareous; and this would seem to be the case here: for the large suboral openings of *Steganoporella* are usually covered with a membrane as in *Steganoporella impressa*, Moll. In a case like the present it is very difficult to distinguish *Steganoporella* from *Micropora*; and I unite this with MacGillivray's species with some hesitation, especially as the avicularia and ovicells are unknown in the fossil.

I have recently received from Miss Jelly a specimen of *Steganoporella perforata* fossil from near Napier, New Zealand. Besides the large pores there are, in one or two cases, pores below these; and then the zoœcia resemble those of *Monoporella lepida*, Hincks. The size and shape of the zoœcia and the size of the oral aperture are the same in *Steganoporella perforata* and *Monoporella lepida*; and I think they must not only be united generically, but can only rank as specific varieties.

9. STEGANOPORELLA MAGNILABRIS, Busk. Plate XXII. figs. 7, 7*a*.

Lepralia firma, Reuss, "Die foss. Anth. d. Schichten von Castelgomberto," Denkschr. Ak. Wien, vol. xxviii. p. 52, pl. xv. fig. 11.

Membranipora magnilabris, Busk, Mar. Poly. p. 62, pl. lxv. fig. 4.

Steganoporella elegans, Smitt (d'Orb.?), Floridan Bry. pt. ii. p. 15, pl. iv. figs. 96–101.

Biflustra crassa, Haswell, "On some Polyzoa from the Queensland Coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. 1, p. 38, pl. i. fig. 8.

Vincularia neozelanica, Busk, Q. J. M. S. new ser. vol. i. 1861, p. 155, pl. xxxiv. figs. 5, 5*a*.

Steganoporella magnilabris, Hincks, Ann. & Mag. Nat. Hist. ser. 5, vol. viii. p. 7.

Steganoporella magnilabris, MacGillivray, Zool. of Victoria, dec. vi. 1881, p. 43, pl. lx. fig. 1.

The Bairnsdale specimens are in the *Eschara*-form; the badly preserved fragment from Mount Gambier is apparently in the *Lepralia*-form. In the Bairnsdale fossil there are two small denticles a small distance down the oral tube, evidently showing the position of the diaphragm, which shuts off the lower portion of the cavity.

Mr. Hincks, in a valuable description of *Steganoporella neozelanica*, Busk (Ann. & Mag. Nat. Hist. ser. 5, vol. ix. Feb. 1882, p. 119, pl. v. fig. 9.), points out the resemblance of *S. magnilabris* and *S. neozelanica*; but, from the examination of specimens in my collection, I am quite unable to understand why Mr. Hincks does not unite them. The width of the aperture in recent and fossil specimens is about 0·38 millim. Mr. Hincks calls attention to this species having being found with various habits of growth in Australia; and the same thing is the case in Florida, and we now also find it to be the case with fossils. I do not change the name to *S. firma*, as I have not had the opportunity of examining any specimen from Mt. Castelgomberto, and the description is not very full.

The lip at the base of the aperture has been called a denticle; but it seems unadvisable to retain this designation, as the term is so frequently used for much smaller structures occurring in the aperture and in pores &c. of the Bryozoa.

Loc. Fossil: Miocene, Castelgomberto (as *L. firma*), Mouille Mougnon (Ste. Croix, Cant. Vaud *), Mt. Gambier, S.W. Victoria. Living: Abrolhos Islet and Algoa Bay (*B.*), as *S. neozelanica*, B., Florida, 15–37 fathoms (*Sm.*), Holborn Island (*Haswell and my coll.*), Bass's Straits (*Hincks*), Queenscliff (*MacG.*).

Mr. Hincks has given a list of recent *Steganoporellæ* and *Microporæ*; and as fossil we may add *Membranipora holostoma*, S. Woods,

* These beds are called Miocene in the Swiss maps; but, so far as I am aware, no fossils have yet been described from them. Besides *S. magnilabris* (in *Eschara*-form), there is a somewhat similar *Steganoporella*, but with much smaller cells and in *Vincularia*-form; also *Myriozoum truncatum*, Pall., *Porella* (*Eschara*) *cervicornis*, M.-Ed. (non Busk), a *Schizoporella* which is common in the Pliocene of Italy, and which may be *Eschara incrassata*, M.-Ed. (non Hincks), and, further, *Echinocyamus pusillus*. From these few fossils the age might be Miocene or Pliocene. These beds are close upon 4000 feet above the sea-level.

M. minuta, Rss., *M. gracilis*, Münst., *M. papyracea*, Rss., *Eschara biseriatopora*, Rss., *E. ignobilis*, Rss., *Vincularia Haidingeri*, Rss., *V. cucullata*, Rss.

10. Cribrilina terminata, Waters. Plate XXII. fig. 6.

Cribrilina terminata, Waters, "Bry. from S.W. Victoria," Quart. Journ. Geol. Soc. vol. xxxvii. p. 326, pl. xvii. fig. 68.

Zoarium in *Eschara*-form. From the Bairnsdale specimens I am able to add a description of the ovicell. It is subimmersed; and in the middle there is a cleft or depression commencing from the distal end of the oral aperture. The upper portion of the ovicell has a second wall raised above the lower one and concealing the cleft, thus forming a cap to the upper part of the ovicell.

11. Cribrilina monoceros, Busk (non Reuss).

Lepralia monoceros, Busk, Mar. Polyzoa, p. 72, pl. xciii. figs. 5, 6.

Lepralia monoceros, MacGillivray, Zool. of Vict. dec. iv. p. 32, pl. xxxviii. figs. 1, 2.

Lepralia monoceros, Ridley, "Zool. Coll. in the Straits of Magellan" &c., Proc. Zool. Soc. 1881, p. 50.

Cribrilina monoceros?, Hincks, "Coll. of Polyzoa from Bass's Straits," Proc. Lit. & Phil. Soc. Liverpool, April 1881, p. 11, & Ann. & Mag. Nat. Hist. July 1881, p. 9, pl. iii. fig. 6.

Zoarium in *Eschara*-form. The shape of the zoœcium, ovicells, avicularia, and spinal attachment corresponds with Busk's figure; and there is no doubt about the identity. Mr. Hincks, however, describes a suboral avicularium, which had not been mentioned by previous authors, and which is absent in the Bairnsdale fossil; and therefore Mr. Hincks's specimen may perhaps be looked upon as a variety. In the aperture there are two projections or teeth above, and two below, reminding us of the aperture of *Cellaria crassa*, &c. I have already called attention (Q. J. G. S. vol. xxxvii. p. 327) when speaking of *Cribrilina dentipora*, to the denticle in the pores of *Cribrilina monoceros* in the British-Museum specimens; Mr. Ridley, in his paper, speaks of a small tubercle projecting into the pore; and in the fossil I find that each pore has a prominent denticle, in each case pointing radially away from the centre of the area.

12. Mucronella mucronata, Smitt.

Escharipora mucronata, Sm. Flor. Bry. p. 24, pl. v. figs. 113–115.

Mucronella mucronata, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 328, pl. xvii. fig. 66, and vol. xxxviii. p. 266.

From Bairnsdale it is in the *Eschara*-form, evidently with a foliaceous growth.

13. Mucronella nitida, Verrill.

Discopora nitida, Verrill, Amer. Journ. Sci. vol. ix. p. 415, pl. vii. fig. 3, 1875.

Mucronella nitida, Verrill, "Recent Add. to Mar. Invert.," Proc. U.S. Nat. Mus. p. 195.

Lepralia reticulata, var. *inæqualis*, Waters, "Bry. of Naples," Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 41, pl. ix. fig. 3.

Loc. Fossil: Crag (*A. W. W.*, cell in *Eschara*-form). Living: Vineyard Sound and Long-Island Sound (*V.*); Naples (*A. W. W.*).

The fossil shows the general character of the species in having the avicularia (which point downwards) very unequal in size.

14. Microporella ciliata, Pall., var.

The specimen from Bairnsdale has small hexagonal zoœcia with a rather smaller aperture than the European specimens in my possession. There are pores all round near the border of the zoœcia, and about six oral spines. Oral aperture 0·08 millim. wide.

15. Microporella elevata, T. Woods.

For synonymy see "Chil. Bry. Mt. Gambier," Q. J. G. S. vol. xxxviii. p. 267.

Loc. Fossil: S.W. Vict. & Mt. Gambier.

16. Microporella decorata, Rss. Plate XXII. fig. 1.

Cellepora decorata, Rss. Foss. Polyp. Wien. Tert. p. 89, pl. x. fig. 25.

Lepralia decorata, Manzoni, Bry. Foss. Ital. 2nda cont. p. 4, pl. i. fig. 6, and Bri. di Castrocaro, p. 15, pl. ii. fig. 18.

Lepralia decorata, Rss. Die foss. Bry. des öst.-ung. Mioc. p. 14, pl. v. fig. 2.

Lepralia decorata, Seguenza, "Le Form. Terz.," Mem. Accad. Lincei, vi. pp. 81, 199, 294.

Lepralia Sturi, Rss. Die foss. Bry. des öst.-ung. Mioc. p. 22, pl. v. fig. 11.

Lepralia Sturi, Seguenza, loc. cit. p. 82.

Lepralia formosa (?), Seguenza, loc. cit. p. 82, pl. viii. fig. 12, p. 199, pl. xiv. fig. 22.

Microporella decorata, Hincks, "Contr. Gen. Hist. Mar. Polyzoa," Ann. & Mag. Nat. Hist. ser. 5, vol. vi. p. 74.

The avicularia are somewhat larger and spread out more than in the European fossils. The specimens seem to be in the *Lepralia*-form. There are five oral spines.

Loc. Living: Madeira 30 fathoms (*H.*). Miocene: Eisenstadt (Hungary), Nussdorf, Mödling. Pliocene: Castrocaro, Parlascio, S. Regola, Modena, Italy (*M.*); in Calabria in the Helvetian, Zanclian, and Astian (*Seg.*).

17. Microporella yarraensis, Waters.

For synonyms see "Chil. Bry. Mt. Gambier," Quart. Journ. Geol. Soc. vol. xxxviii. p. 267.

18. Microporella violacea, Johnst.

Only a small fragment.

19. Porina coronata, Rss.

For synonyms and localities see "Bry. S.W. Victoria," loc. cit. p. 333.

20. PORINA LARVALIS, MacG.

Lepralia larvalis, MacGillivray, Zool. of Vict. dec. iv. p. 30, pl. xxxvii. fig. 5.

Porina larvalis, Waters, "Chil. Bry. from Mt. Gambier," Q. J. G. S. vol. xxxviii. p. 269, pl. viii. fig. 19.

Loc. Living: Williamstown (*MacG.*), Bondi Bay and Semaphore (*A. W. W.*). Fossil: Mt. Gambier.

21. LEPRALIA DEPRESSA, Busk, var.

Lepralia depressa, Busk, Mar. Polyzoa, p. 75, pl. xci. figs. 3, 4.

Zoarium in *Lepralia*-form. Zoœcia large, subhexagonal, convex, smooth, aperture contracted in the middle, about 0·10 millim. at the widest part. Avicularian or vibraculoid process on each side nearly half down the cell.

This differs from *Escharella setigera*, Smitt (Flor. Bry. p. 58, fig. 206), in the position of the avicularian or vibraculoid process, which occurs halfway down the cell, in about the same position as in *Schizoporella vulgaris*, Moll, whereas in *E. setigera* from Florida it is near the top of the cell, in the same position as in *Mastigophora Dutertrei*, Aud. It also differs from *L. depressa* from the Ægean Sea in not having a vibraculum on a level with the mouth.

22. LEPRALIA BURLINGTONIENSIS, Waters, "Chil. Bry. Mt. Gambier," Q. J. G. S. vol. xxxviii. p. 270, pl. vii. fig. 6.

23. LEPRALIA BAIRNSDALEI, sp. nov.

Zoarium in *Eschara*-form. Zoœcia subrectangular or contracted below, bounded by broad, much raised lines, surface consequently depressed; large pores and large granulations with large pores round the edge of the zoœcium. Oral aperture contracted in the middle by means of a denticle on each side some little distance down the aperture. An oral avicularium in the aperture or just below it.

This shows many points of similarity with *Porella nitidissima*, Hincks; but the lateral avicularia are wanting in the present species, and Hincks does not find any lateral contractions in the aperture. It differs from *Smittia seriata*, Rss., in having no proximal denticle.

24. LEPRALIA GIPPSLANDII, sp. nov. Plate XXII. fig. 12.

Lepralia-form. Zoœcia ovate, surface minutely punctate. Oral aperture almost circular. Ovicell globose, punctate. Although the specimen is well preserved, there are so few characters that it is impossible to be quite sure that it has not previously been described.

25. LEPRALIA FOLIACEA, Ell. & Sol.

Lepralia foliacea, Waters, "Chil. Bry. Mt. Gambier," Q. J. G. S. vol. xxxviii. p. 269, pl. vii. fig. 3.

As I mentioned, when speaking of the Mt.-Gambier specimens, there are two varieties from Bairnsdale (both in *Eschara*-form), one

with an avicularium in the mouth and punctured all over the surface, the other as fig. 3; and within the last few days Miss Jelly has sent me a specimen of this last, which she found in her collection from S.W. Victoria. It is better preserved than the others, showing the acute shape of the small avicularia, which point downwards; and there are also ovicells preserved, which are very little raised. The shell-structure of the central part of the ovicell is much thinner than the front wall of the zoœcia; and this thinner part is surrounded by a broad band.

The ovicells of *L. foliacea* seem seldom to have been found; and as in this case they are less raised than in my Naples specimens, and are also surrounded by a broad border, it must be looked upon as a distinct variety; or possibly it will have to be specifically separated.

26. Porella denticulata, Stoliczka.

Flustrellaria denticulata, Stol. Foss. Bry. Orak. p. 138, pl. xx. fig. 2.

Porella denticulata, Waters, "Bry. S.W. Vict." Q. J. G. S. vol. xxxvii. p. 336, pl. xvii. fig. 70.

Loc. Fossil: Orakei Bay (*Stol.*); S.W. Victoria.

27. Smittia Tatei, Tenison Woods.

Eschara Tatei, T. W. "On some Tert. Austr. Fossils," Tr. Roy. Soc. N. S. W. 1876, p. 3, fig. xv.

Smittia Tatei, Waters, "Bry. S.W. Vict." Q. J. G. S. vol. xxxvii. p. 337, and "Bry. Mt. Gambier," loc. cit. vol. xxxviii. p. 271, pl. vii. fig. 10, pl. viii. fig. 21.

28. Smittia reticulata, MacG.

29. Smittia anceps, MacG.

Lepralia anceps, MacGillivray, Zool. of Vict. dec. iv. p. 23, pl. xxxv. fig. 6.

Smittia anceps, Waters, Q. J. G. S. vol. xxxvii. p. 337, pl. xviii. fig. 94.

The separating lines between the zoœcia are much raised; and as the colony is fertile, it has much more the appearance figured by MacGillivray than the specimen from S.W. Victoria. The surface is coarsely granular; and the raised ovicell occupies the greater part of the front of the zoœcium.

30. Schizoporella phymatopora, Reuss.

Eschara phymatopora, Reuss, Foss. Anth. & Bry. v. Crosaro, p. 272, pl. xxxiii. fig. 1.

Schizoporella phymatopora, Waters, "Bry. S.W. Vict." Q. J. G. S. vol. xxxvii. p. 338, pl. xv. figs. 31, 32.

The zoaria from Bairnsdale consist of hollow cylinders about 3 mm. in diameter. In some specimens the zoœcia form transverse series, in others they are alternate—showing that the fact of the zoœcia being arranged transversely cannot be made a specific character, much less generic, as was done with *Melicerita*. It is still a character used in classifying the Cyclostomata.

The avicularia are directed upwards.

Loc. Bartonian, Val di Lonte & Ferrara di Monte Baldo (Italy); S. W. Victoria (*A. W. W.*).

31. Schizoporella auriculata, Hass.

Lepralia- and perhaps *Hemeschara*-form.

32. Schizoporella acuminata, Hincks.

For synonyms see Q. J. G. S. vol. xxxviii. p. 274.

In cells where the pointed character of the distal end of the cell and also the avicularia are wanting, the appearance is much the same as that of *Schizoporella Cecilii*, Aud.

33. Schizoporella bombycina, Waters.

Q. J. G. S. vol. xxxviii. p. 274, pl. ix. fig. 36.

34. Schizoporella ventricosa, Hasw.

Onchopora ventricosa, Haswell, "On some Polyzoa from the Queensland coast," Proc. Linn. Soc. N. S. Wales, vol. v. pt. 1, p. 36, pl. i. fig. 3.

Loc. Living: Holborn Island, 20 fath. Fossil: S. W. Vict.

35. Palmicellaria Skenei, Ell. & Sol. Plate XXII. fig. 9.

Lepralia bicornis, Busk, Crag Polyzoa, p. 47, pl. viii. figs. 6, 7.

Palmicellaria Skenei, var. β, Hincks, Brit. Mar. Polyzoa, p. 380, pl. lii. fig. 4.

From the state of preservation the characters are not well marked; but on each side of the aperture there is a process, and in front an avicularian umbo. In using the above nomenclature I am following Mr. Hincks; and the present specimen does not furnish the opportunity of checking the generic position. I am not sure whether the notch sometimes seen in the front of the aperture is an incision in the peristome or an oral sinus.

Loc. Fossil: Crag (?). Living: Northern Seas.

36. Retepora marsupiata, Smitt.

See Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 342, pl. xv. figs. 34, 35, 36, pl. xvii. figs. 59, 61, 76, 77.

Loc. Fossil: S. W. Victoria, Mt. Gambier, Miocene of S. Barbara, U. S. Living: Florida, Teneriffe.

37. Retepora rimata, Waters.

See Waters, *loc. cit.* p. 343, pl. xvi. figs. 48, 53, and vol. xxxviii. p. 275.

Loc. Fossil: S. W. Victoria and Mt. Gambier.

38. Retepora deserta, sp. nov.

Zoarium cup-shaped, fenestrate, branches connected laterally by small round bars without any zoœcia; dorsal surface of zoarium plain.

Zoœcia ovate, smooth, with a broad raised avicularium at one

side; mandible turned sideways, apex directed upwards. Ovicell? There is a sinus in the round aperture; but I am not quite sure whether this is a primary or secondary character.

The transverse bars without cells and the suboblong fenestræ thus caused give the colony the appearance of some of the *Fenestellidæ*.

The shape of the zoœcia and avicularia is the same as in *Cellepora ramulosa* (see Smitt, Öfv. K. Vetensk. Ak. Förh. 1867, tab. xxviii. fig. 188). This may be closely related to *Discopora albirostris*, Smitt (Flor. Bry.).

39. Cellepora yarraensis, Waters. Plate XXII. fig. 8.

Cellepora yarraensis, Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 343, and vol. xxxviii. p. 275.

Loc. S.W. Victoria and Mount Gambier.

40. Cellepora albicans, Hincks.

Monoporella albicans, Hincks, "Contr. towards Gen. Hist. of Mar. Polyzoa," Ann. & Mag. Nat. Hist. Feb. 1882, ser. 5, vol. ix. p. 123, pl. v. figs. 5, 5 *a*, 5 *b*.

I have already pointed out that probably, on account of the shape of the aperture, *Cellepora sardonica*, Waters, *C. yarraensis*, W., *C. intermedia*, MacG., *C. compressa*, Busk, and *Cellepora fossa*, Hasw., should be formed into a subgenus; and the present form should be added to the list. I am not, however, inclined to think that they will ultimately find their place with *Monoporella*, and therefore provisionally leave this with *Cellepora*.

41. Cellepora pumicosa, Busk (non L.).

Only a small fragment. This has a very prominent rostrum; and the avicularia inside the rostrum are acute and placed laterally instead of diagonally or longitudinally.

42. Lunulites cancellatus, Busk. Plate XXII. figs. 10, 11.

Lunulites cancellata, Busk, Cat. Mar. Polyzoa, p. 101, pl. cxiii. figs. 4–7; Waters, Quart. Journ. Geol. Soc. vol. xxxvii. p. 344, and vol. xxxviii. p. 275.

Zoarium 4–5 millim. diameter, 2 millim. high, conical; aperture elongate. At some distance down the aperture there is a secondary aperture with a notch in the proximal end.

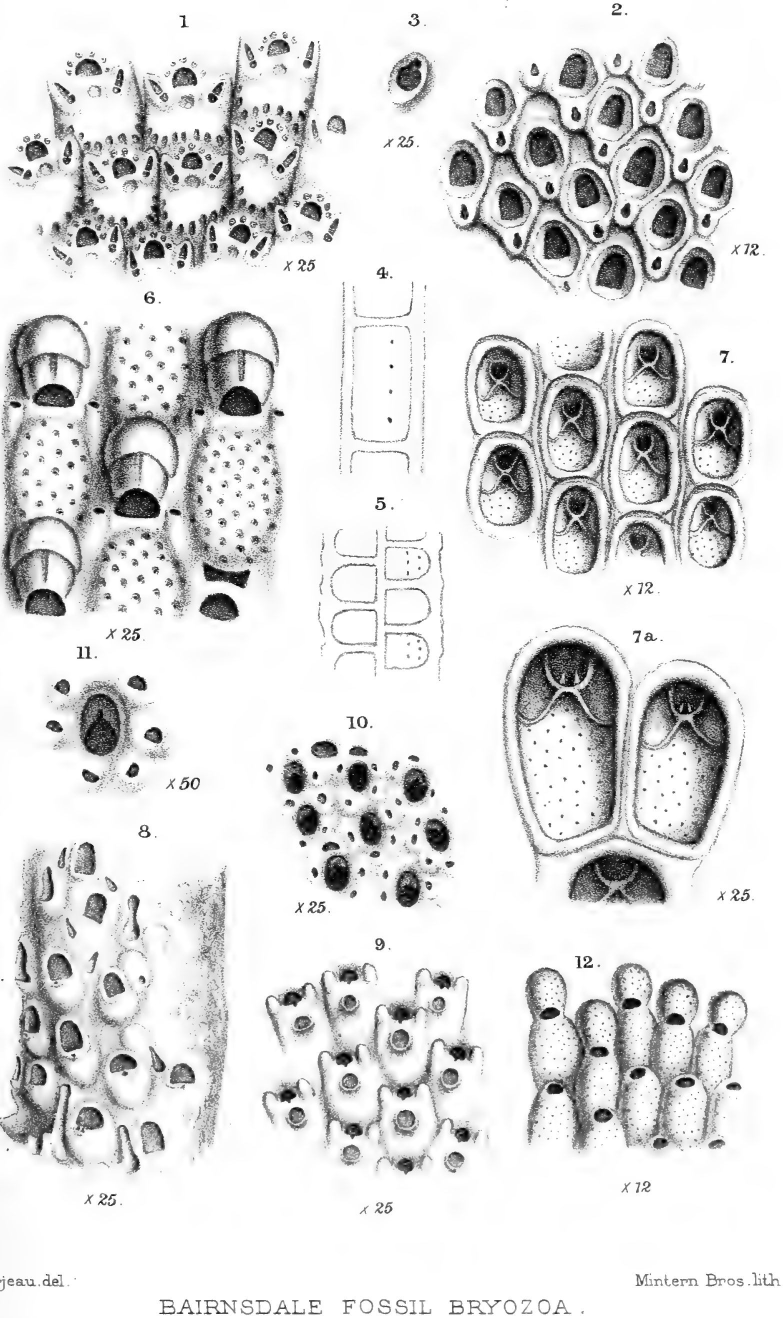
Loc. Living: Philippine Islands and New Guinea. Fossil: S. W. Victoria and Mt. Gambier.

Addendum.

Shortly after the completion of this paper, Miss Jelly found in her collection from S.W. Victoria some specimens which had not been submitted to me. As they are of considerable interest, I add a description of them as a note to this paper, so as to conclude the series on the Chilostomata.

Mucronella porosa, Hincks.

Mucronella porosa, Hincks, "Gen. Hist. of Mar. Polyzoa," Ann. & Mag. Nat. Hist. ser. 5, vol. viii. p. 124, pl. i. fig. 5.



C. Berjeau del.

Mintern Bros. lith.

BAIRNSDALE FOSSIL BRYOZOA.

In the fossil there is on each side of the mucro an erect spinous process, at the top of which is a small spatulate avicularium. In a recent specimen in my possession from Tasmania there is a spinous process on each side; but these never seem to be avicularian.

In the fossil as well as in the Tasmanian specimen there is very frequently on one side, near the border and about halfway down the zoœcium, a small, nearly round avicularium.

The spinous process, which in some cases is avicularian, is one of those instances, now rather numerous, which, it seems to me, must ultimately lead to our seeing that the function of the avicularia is not prehensile, as formerly supposed.

Loc. Living: Curtis Island (*H.*), Singapore or Philippine Islands (*Miss J.*), Tasmania (*sent me by Miss Gatty*). Fossil: S. W. Victoria.

SMITTIA BIINCISA, Waters.

Smittia biincisa, Waters, Q. J. G. S. vol. xxxviii. p. 272, pl. vii. fig. 1.

The S.W.-Victorian specimen is better preserved than those from Mt. Gambier, and shows five oral spines.

Loc. Mt. Gambier.

MEMBRANIPORA RADICIFERA, Hincks.

Membranipora radicifera, Hincks, Ann. & Mag. Nat. Hist. s. 5, vol. viii. p. 5, pl. ii. fig. 6.

Membranipora radicifera, Waters, Chil. Bry. Mt. Gambier, Q. J. G. S. vol. xxxviii. p. 262, pl. ix. figs. 26, 27.

The dorsal surface has several protuberances to each zoœcium; and these were apparently perforated; but it is impossible to say whether there were radicular appendages.

EXPLANATION OF PLATE XXII.

Fig. 1. *Microporella decorata*, Rss., × 25.
2. *Membranipora appendiculata*, Rss., × 12.
3. Ditto, avicularium, × 25.
4. Ditto, lateral rosette-plates (diagrammatic).
5. Ditto, distal ditto.
6. *Cribrilina terminata*, Waters, × 25.
7. *Steganoporella magnilabris*, Busk, × 12.
7 *a*. Ditto, held diagonally, in order to examine the tubular aperture, × 25.
8. *Cellepora yarraensis*, Waters, × 25.
9. *Palmicellaria Skenei*, Ell. & Sol., × 25.
10. *Lunulites cancellatus*, Busk, × 25.
11. Ditto, aperture, × 50.
12. *Lepralia gippslandii*, sp. nov., × 12.

DISCUSSION.

Dr. MURIE said that the Society was much indebted to Mr. Waters for his laborious work on a difficult branch of investigation. The methods of classification proposed by him had now been adopted by several authorities of weight.

48. *On the* Silurian (*and* Cambrian) Strata *of the* Baltic Provinces *of* Russia, *as compared with those of* Scandinavia *and the* British Isles. By Professor F. Schmidt, St. Petersburg. (Read June 21, 1882.) Communicated by Dr. Henry Woodward, F.R.S., F.G.S.

[Plate XXIII.]

Introduction.

I have recently completed the first part of a memoir upon the Silurian Trilobites of the Baltic provinces of Russia *, containing a special geological introduction. This work is already in the hands of Silurian geologists. But as the subject of my memoir, and more particularly its geological introduction, may be of interest to British geologists in general, I will here endeavour to develop in English the most important results of my investigations, pointing out at the same time more especially some difficulties and controverted points in the parallelization of our Silurian strata with those of Scandinavia and the British Islands. There is no map accompanying my memoir; and the reader is therein requested to refer to the geological map of the Baltic provinces of Russia, published at Dorpat in 1878 by Prof. Grewingk. In this map the Silurian part was drawn by myself. The accompanying sketch (Pl. XXIII. fig. 1). will serve the purpose of the present paper.

General Characteristics.

The whole of our so-called Eastern Baltic Silurian spreads over a large area, of an average length of 400 English miles and a breadth of 80 miles, through the provinces of Ingermanland (St. Petersburg), Esthonia, Livonia, and the island of Oesel. It forms one complete series of conformably arranged strata. This series is entirely independent of the Devonian, which covers the Lower Silurian in the east, and the Upper Silurian in the west, without showing any connecting intermediate links. The surface of the country occupied by our system forms a nearly uniform plain (in some parts of the country scattered over with narrow ridges or *åsar* of glacial origin). It is slightly inclined S. and S.W., and broken abruptly off at its northern border, in cliffs from 50 to 150 feet high (the so-called "Glint" along the southern coast of the Gulf of Finland; see the woodcut in Murchison's 'Siluria,' 1867, p. 356, and our section, Pl. XXIII. fig. 3). The lowest stages are visible only in these northern cliffs and in river-sections near the northern border of our system; the others appear as low terraces in the interior of the country, and are represented on

* "Revision der ost-baltischen silurischen Trilobiten, nebst geognostischer Uebersicht des ost-baltischen Silurgebietes, von F. Schmidt. Abtheilung 1, Phacopiden, Cheiruriden, und Encrinuriden, mit 16 Tafeln," Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg, 7[me] série, tome xxx. no. 1. St. Pétersbourg, 1881.

the map as well-marked zones stretching in a direction nearly parallel to the north coast, and following each other from N. to S., or from N.E. to S.W., according to the inclination of the strata.

In my former publication on our Silurian ('Untersuchungen über die silurische Formation von Ehstland, Nord-Livland und Oesel,' Dorpat, 1858) I marked only the zones represented on the map of the plain itself, with the numbers from 1 to 8, leaving the lower stages (visible only in the cliffs) without a corresponding notation. I have now introduced a new designation, by letters from A to K ; the lowest stages, A and B, in most parts of the country, however, are visible only in the northern cliffs and in corresponding river-sections.

In the northern cliffs the superposition of the stages is directly observable, and also in some of the zones of the interior; in others it is only assumed, but may be actually observed in neighbouring Silurian countries where the same arrangement of strata occurs, as, for instance, in Sweden or Norway. The stages of the interior all consist of limestones and marls, showing thus a continuous development of marine life from the beginning of the Lower Silurian to the end of the Upper, without any remarkable changes of physical conditions. The zoological character of each zone is extremely constant, though there exist very close relations between the faunas of neighbouring zones. As most of the zones stretch over a large area as long and narrow nearly parallel bands, the before-mentioned uniformity of their faunas affords us the means by which to check the value of differences between allied species of different zones, and allows us to study at the same time the variations of species both in time and space.

Principal Divisions.

Three clear principal divisions of the whole series can be distinguished, the same as everywhere, but most nearly allied to those of Sweden; and therefore the same nomenclature is adopted by me in the same sense as used in Sweden by Linnarsson and others. The divisions are:—(1) the Cambrian or Primordial Silurian (stage A) = Cambrian of Dr. Hicks; (2) the Lower Silurian (stages B–F), nearly equal to the Ordovician of Lapworth; and (3) the Upper Silurian (stages G–K), the Silurian of Sedgwick. According to the geological conditions of our country, I should rather prefer to regard our whole series of strata as one system, the Cambrian being only a part of it—because all the strata are arranged conformably, and the whole is covered unconformably by the Devonian, the connecting lowest Devonian stages being altogether unrepresented with us.

The three principal divisions are easily recognizable with us, as there do not exist any connecting links, and the palæontological breaks are very clear between the Cambrian and the Lower Silurian as well as between the latter and the Upper Silurian. Our so-called Cambrian is entirely formed of sandstone, clay, and shale; both Silurian divisions are purely limestones and marls, with very insig-

nificant thin layers of sandstone. As to the Lower and Upper Silurians, there cannot be any question as to their representing the same divisions as in Scandinavia and the British Islands, *i.e.* the second and third faunas of Barrande; but our Cambrian or Primordial Silurian I admit to be disputable, because of its peculiar constitution. No Primordial Trilobites of the *Paradoxides* or *Olenus* group are found with us—indeed, no Trilobites at all, only Lingulidæ, some Graptolites (including *Dictyonema*) in the uppermost stage, and some doubtful additional organic remains (see woodcuts 1–3 on page 13 of my memoir above cited). My opinion as to the existence of the Cambrian in our country is founded upon the identity of the highest Cambrian (the *Dictyonema*-shale) and the lowest Silurian strata in Russia and in Scandinavia, and upon the agreement of the Scandinavian geologists Linnarsson and Brögger, who both visited at different times our most important localities, and who were at the same time well acquainted with the geology of their own country.

Cambrian Strata.

(*Stage* A.)

Our Cambrian strata are visible (as I mentioned before) only in the cliffs at the northern border of our system and in corresponding river-valleys from the S.E. corner of the Ladoga, at the rivers Walchow and Sjas, to the cliffs near Baltischport on the Gulf of Finland, a distance of about 500 versts. Three stages of these strata have long been known:—(1) the Blue Clay, (2) the Ungulite Grit, and (3) the *Dictyonema*-slates. All these stages are exposed in many places along the northern cliffs; but their thickness (all three stages taken together), as visible in natural sections, does not exceed 100 feet. Yet the artesian wells in Reval and St. Petersburg have shown an amount of about 600 feet more, the Blue Clay reaching a thickness of 300 feet, and the underlying iron-sandstones about the same. The latter repose directly upon granite in the artesian well at St. Petersburg (Gen. Helmersen, Bullet. de l'Acad. St. Pétersb. 1865, p. 185). In the upper strata of the Blue Clay some strange and very minute fossils have been found, called by Pander *Platysolenites* (see my memoir, p. 13, woodcut, fig. 1): they may be either Annelide-tubes or flattened stalks of some unknown Cystidean (as they show a distinct articulation). At the upper edge of the clay we often detect thin layers of intercalated sandstone filled with green agglomerated corpuscles resembling casts of Foraminifera (my memoir, p. 13, fig. 2). The so-called Ungulite Grit has an average thickness of 50–60 feet; its lower strata pass gradually into the Blue Clay by frequent intercalations of clayey bands. In these intercalated clay beds Dr. Volborth has found some doubtful minute Orthoceratites (see fig. 3 on p. 13 of my memoir). The Ungulites themselves are found only near the upper edge of the so-called Ungulite Grit. These real Ungulite layers are crowded with millions of separated valves of *Obolus apollinis*, Eichw. (*Ungula*, Eichw.), with which are associated in some places, forming distinct layers, *Schmidtia celata*,

Volb., *Helmersonia*, Pand., and *Keyserlingia*, Pand. This typical Ungulite Grit attains a thickness of not more than three or four feet; it is very often intercalated with thin bands of the strata of the succeeding stage.

This stage (3), the *Dictyonema*-slate, is the highest member of our Cambrian series, and a very important one too, as it is the only indubitable connecting link between our Cambrian and that of Scandinavia. The *Dictyonema*-slate has a thickness of from 1 to 10 feet, and is exactly identical with the same stage as developed in Sweden and Norway. It must be looked upon as a direct continuation of the Swedish *Dictyonema*-slate, its petrological character being the same. The characteristic species, *Dictyonema flabelliforme*, Eichw., of the beds in both countries is the same; and, moreover, the geological position, as shown by the succeeding stages of the Glauconitic and Orthoceratite Limestone, is correspondent. As the *Dictyonema*-slate in Sweden is intimately connected with the *Olenus*-beds, and, with us, with the Ungulite-beds, the latter may possibly be regarded as a coast-facies of the *Olenus*-stage of the Swedish Cambrian. The lower sands and the Blue Clay must consequently also correspond to some part of the Swedish Cambrian; yet it is difficult to say to which of them, identical fossils being altogether wanting. The lithological character of the lowest sandstone (near to the Blue Clay) reminded Dr. Linnarsson of some beds of the Swedish *Eophyton*-sandstone, Annelide-tracks and *Cruziana*, as in W. Gothland, being also visible with us. The *Dictyonema*-slate in some places shows, besides the *Dictyonema*, also some Graptolites (my memoir, p. 16, fig. 4). These I believe to be identical with *Bryograptus Kjerulfi*, Lapw., as figured by Kjerulf in his Veiviser ved geologiske Excursioner i Christiania omegn, p. 3, fig. 6.

In England the *Dictyonema*-beds have a corresponding position at the top of the Cambrian (in the sense of Hicks and Lapworth) in the lower Tremadoc (*cf.* Lapworth in the Geol. Mag. 1881, p. 320); yet the identity of *Dictyonema sociale*, Salt., with *D. flabelliforme*, Eichw., though asserted by Törnqvist, is not, in my opinion, fully decided. The Norwegian *D. norvegicum* and *D. graptolithinum* of Kjerulf are, as asserted by Brögger, exactly the same as our *D. flabelliforme*.

To complete the account of our Cambrian strata, we may admit that the development of the Cambrian system or division is not typical with us; yet the strata of these stages cannot be compared to any excepting those of the Cambrian stages of other Palæozoic countries, and therefore they must be regarded as representing the Cambrian or Primordial Silurian with us.

Lower Silurian Strata (*Ordovician*, Lapw.).

The Lower Silurian (Ordovician, Lapw.) is the richest among our divisions. Nowhere else, I believe, has such a regular undisturbed development obtained of this part of the Palæozoic formations. In other countries there are several breaks, caused by interchange of

limestone and slaty rocks. With us the whole of the Lower Silurian (with the exception of the very lowest stage) is formed of limestones only, deposited in one and the same ancient ocean, without any remarkable change of physical conditions, and without any interruption in the evolution of animal life. Hence it will be possible with us to follow the minute changes produced by time in the form of marine organisms (mutations), especially as our widespread zones enable us at the same time to study the variations of the same organisms in space.

Stage B (B 1, *Glauconite Sand*; B 2, *Glauconite Limestone*; B 3, *Orthoceratite Limestone*).

We enumerate five principal stages in our Lower Silurian, distinguished by the letters B, C, D, E, and F; but several of these can be subdivided into two or more substages. For example, the first stage, B, might be regarded as composed of two or three different stages; they have been united mainly as a matter of convenience.

B 1, *Glauconite Sand.*—The first subdivision, B 1, is the so-called Greensand, or Glauconite Sand. It has a thickness of from 1 to 10 feet, and covers the *Dictyonema*-slate everywhere in the northern cliffs of Esthonia, and in the prolongation of these cliffs throughout the government of St. Petersburg, as far as the lower Wolchow. The lower part of this subdivision is comparatively sandy, the upper somewhat clayey. The predominating green colour is produced by agglomerated grains similar to those formerly mentioned as occurring in the sandy layers at the top of the Blue Clay. These grains were regarded by Ehrenberg as casts of Foraminifera and small Pteropoda; and he has described and named several of them in the 'Monatsberichte' of the Berlin Academy, 1861. In the same layers, principally in the clayey ones, are found the famous Conodonts of Pander (they begin here, but are found also in higher stages), the real zoological position of which has hitherto been uncertain; of other fossils are found only *Obolus siluricus*, Eichw., a peculiar *Siphonotreta*, and a rather variable *Lingula*, reminding us, by its somewhat pentagonal form, of *Lingulella Davisi*, M'Coy (see my memoir, p. 17, fig. 5). In geological position our Glauconite Sand corresponds exactly to the *Ceratopyge*-stage of Scandinavian geologists, although no traces of Trilobites are found. The systematic position of the Glauconite Sand, occurring, as it does, between the *Dictyonema*-slate and the Glauconite Limestone (the Lower *Orthoceratite*-limestone of Sweden) will not allow of any other parallelization. In England the Upper Tremadoc may be the corresponding stage; yet *Lingula Davisii* commences its range there at a much earlier date.

B 2, *Glauconite Limestone.*—The second substage, B 2, of our stage B is the so-called Glauconite Limestone. It attains a thickness of 12–40 feet, the thickness increasing to the eastward. The uppermost layers of the clayey beds of the Greensand become impregnated with carbonate of lime, and are in this way intimately linked to the Glauconite Limestone. The same glauconitic grains do exist in the limestone; but they are more scattered, and the limestone becomes in con-

sequence of a lighter green than the sand. Sometimes the limestone is of a reddish tinge, with intercalated dark-green grains, principally in the lower strata. The zoological character of the Silurian fauna seems to have suddenly changed at the commencement of the Limestone period. With the earliest Limestone bed several Trilobites appear. The most characteristic form for this substage is *Megalaspis planilimbata*, Ang. In addition there are found other Asaphidæ, and *Cheirurus clavifrons*, Dalm. The predominating Brachiopoda are *Porambonites reticulatus*, Pand., *Orthis parva*, Pand., *O. extensa*, Pand., *O. callactis*, Dalm., and *Orthisina plana*, Pand. Cephalopoda and Gasteropoda, however, are wanting. In the higher strata of the Glauconite Limestone the glauconitic grains become smaller, and the limestone becomes softer and marly. Here is the true horizon of the well-known *Asaphus expansus*, Dalm., so frequently confounded with other species of the genus. In addition, we have other Asaphidæ, as *A. angustifrons*, Dalm., and the large forms *A. centron*, Leuchtbg., and *acuticauda*, Ang.; *Cheirurus clavifrons* becomes more frequent; *Phacops* (*Pterygometopus*) *sclerops*, Dalm., and the first representatives of *Illænus*, *Lichas*, and *Ampyx* appear, also the first Cystidean forms, *Glyptocystites giganteus*, Leuchtbg., and *Echinoencrinites angulatus*, Pand. Among others occur the first Chætetidæ and *Bolboporites australis*, Pand. This upper part of the Glauconite Limestone is more richly developed on the lower Wolchow at the S.E. end of Lake Ladoga. The lower part, with *Megalaspis planilimbata*, has everywhere the same aspect, from the Wolchow as far as Baltischport on the Gulf of Finland, a distance of more than 300 English miles.

B 3, *Orthoceratite Limestone.*—The succeeding stage, B 3, is the famous Vaginaten- or Orthoceratite Limestone. It has a relatively small thickness with us, from 3 to 20 feet; but the zoological character of the fauna is remarkably constant, not only here, but also in Scandinavia. In most places this stage consists of a hard grey limestone, and is crowded with the well-known Orthoceratites *O. communis* (*duplex*), Wahlb., and *O. vaginata*, Schloth. To the west of Reval it gradually passes into a sandstone: the Orthoceratites disappear; but the other characteristic fossils remain. In the east (for example, upon the Wolchow) there is a gradual passage from the upper beds of the Glauconite Limestone to the Vaginaten-Limestone; but in Esthonia we commonly find, at the base of the latter, a layer of about 2–3 feet thickness, filled with larger or smaller concretions of phosphate of lime, sometimes assuming a pisolitic character. The fauna of the Orthoceratite Limestone is generally well known both with us and in Scandinavia. Among Trilobites we may name *Phacops sclerops* and *trigonocephalus*, *Cheirurus ornatus*, Dalm., *clavifrons*, Dalm., and *affinis*, Ang., *Cybele bellatula*, Dalm., *Lichas celorrhin*, Ang., and *verrucosa*, Eichw. (*convexa*, Ang.), *Amphion Fischeri*, Eichw., *Illænus Wahlenbergi*, Eichw., *Asaphus heros*, Dalm., *Ptychopyge globifrons*, Eichw., *Ampyx nasutus*, &c. Among Cephalopoda we find, in addition to the common Orthoceratites, *Lituites lamellosus*, His. (*convolvens* auct.), *L. falcatus*,

Quenst., *Gomphoceras Eichwaldi*, &c.: among Gasteropoda, *Euomphalus Gualteriatus*, Eichw., *Maclurea helix*, Eichw., *Metoptoma silurica*, Eichw., *Bellerophon locator*, Eichw.; among Lamellibranchiata, *Megalodon unguis*, Eichw. Both classes, Gasteropoda and Lamellibranchiata, appear here for the first time with us; *Hyolites* and *Conularia* also appear for the first time at this stage. Among Brachiopoda, we find *Orthisina concava*, Pahlen, *O. plana*, Pand., *Crania antiquissima*, Eichw., *Siphonotreta verrucosa*, Eichw., &c. The other classes show no difference from those of the preceding stage. Yet I must mention that in the lower part of the Orthoceratite Limestone in Esthonia I found a very fine specimen of *Phyllograptus*, interesting from a stratigraphical point of view, as it renders it possible to parallelize our Orthoceratite Limestone with the Arenig of England. In Sweden, according to Törnqvist, the *Phyllograptus*-schist is intercalated in the *Orthoceras*-limestone; and the same author has already pointed out the similarity of the above-mentioned *Phyllograptus*-schists and the British Arenig.

Stage C. C 1, *Echinosphærite Limestone &c.*

The third principal stage, C, of our Lower Silurian may also be subdivided into three smaller stages. The first, C 1, is the widely spread *Echinosphærites*-limestone. We may follow it from the Wolchow throughout our whole Silurian country as far as the island of Odensholm, and thence all over Scandinavia. Its thickness may be from 20 to 50 feet. By far the most characteristic fossils are *Echinosphærites aurantium*, Gyll., and *Orthoceras regulare*, Schloth., the former predominating in the upper part of our stage, the latter in the lower, although it certainly is not possible to trace all over the country two subdivisions individualized by the above-named fossils. Our stage C 1 is the richest in Trilobites, and is also very rich in many other classes: yet our knowledge of the fauna is by no means complete, and every year some new species may be discovered. The character of the fauna is not at all uniform; and many local faunas might be distinguished. Among Trilobites we find *Phacops* (*Pterygometopus*) *Panderi*, mihi, the first species of the subgenus *Chasmops*, namely *P.* (*C.*) *nasuta*, mihi, *præcurrens*, mihi, and *Odini*, Eichw., *Cheirurus exsul*, Beyr., the subgenus *Nieszkowskia* with *Cheirurus variolaris*, Linnars., and *Cheirurus gibbus*, Ang., *Illænus Schmidti*, Niesz., *tauricornis*, Kut., *Dalmanni*, Volb., *Asaphus Weissii*, Eichw., *Kowalewskii*, Lawr., *devexus*, Eichw., *delphinus*, Lawr., *tecticaudatus*, Steinh., *Lichas tricuspidata*, Beyr., and others; among Cephalopoda, *Lituites perfectus*, Wahlenb., (*Orth. undulatus*, Quenst.), *teres*, Eichw. (both in the lower stage), *Palæonautilus Odini*, Eichw., Röm., *Orthoceras regulare*, Schl., *vertebrale*, Eichw., *Cyrtoceras Odini*, Eichw.; among Gasteropoda, *Pleurotomaria elliptica*, His., *Ecculiomphalus alatus*, Röm., *Subulites priscus*, Eichw., *Bellerophon megalostoma*, and many others; among Acephala a good many forms of *Modiolopsis*, and allied genera not yet well determined; among Brachiopoda, *Orthisina ascendens*, Pand., *O. hemipronites*, Buch, *O. squamata*, Pahlen, *O. pyrum*,

Eichw., *Leptæna transversa*, Pand., *L. convexa*, Pand., *L. oblonga*, Pand., *Strophomena imbrex*, Pand., *Porambonites æquirostris*, Pand., *P. deformatus*, Eichw., *Orthis lynx*, Eichw., *O. calligramma*, Dalm., &c.; among Echinodermata, the Cystideans *Echinosphærites aurantium*, Gyll., *E. balticus*, Eichw., *Hemicosmites malum*, Eichw., and our oldest Crinoid *Hybocrinus dipentas*, Leucht. True corals do not yet exist; but the typical *Chætetes petropolitana*, Pand., *C. heterosolen*, Keys., and *C. Panderi*, E. & H., occur very often.

This stage corresponds to the uppermost Orthoceratite Limestone of Sweden, as developed in Oeland and Westrogothia, and also to the lower part of the *Chasmops*-limestone of the same regions. The Cystidean limestone of Törnqvist in Dalarne answers fairly well to our stage. Even in Norway our stage has corresponding strata, according to Prof. Brögger. In the British Islands it is not possible to detect parallel stages; but in Canada, some parts of the Quebec group containing *Cheirurus vulcanus*, *C. perforator*, and *C. glaucus* may furnish material for comparison.

C 2, *Kuckers Shale* (Brandschiefer).

The upper stage of our group C, *i. e.* C 2, is very marly. It is connected with C 1, as regards the fauna, but differs in its lithological aspect, as the stage is characterized by bituminous marls and limestones. This stage I can distinguish only west of St. Petersburg, from Djatlizy, as far as Odensholm, at the western angle of Esthonia. East of St. Petersburg the Echinosphærite Limestone is directly covered by the Devonian. The stage C 2 excels all other stages among our Silurian strata by its beautifully preserved fossils. The best locality is Kuckers near Tewe, and I have given it the local title of the 'Kuckers zone.' In the bituminous marls all the minor forms of *Beyrichiæ*, Bryozoa, &c. are wonderfully well preserved; and hence we can form a vivid idea of the old Silurian marine life. The thickness of the stage may be estimated at 30–50 feet. The fauna is very similar to that of stage C 1, as I have already pointed out; but yet some species have disappeared, and other allied ones have taken their places. Among Trilobites I shall name *Phacops exilis*, Eichw., *P.* (*Chasmops*) *Odini*, Eichw., *Cheirurus spinulosus*, Nieszk., *C.* (*Nieszkowskia*) *cephaloceras*, Nieszk., *Lichas conicotuberculata*, Nieszk., *Cybele rex*, Nieszk., *revaliensis*, mihi, and others. Among other classes *Pleurotomaria elliptica*, His., *Subulites priscus*, Eichw., *Bellerophon Czekanowskii*, mihi, *Hyolites striatus*, Eichw., *Nucula ædilis* and *N. macromya*, Eichw., *Siphonotreta unguiculata*, Eichw., *Pseudocrania planissima*, Eichw., *Porambonites teretior*, Eichw., *Orthisina squamata*, Pahlen, *O. marginata*, Pahlen, *Orthis lynx*, Eichw., *O. dorsata*, His., *Echinosphærites aurantium*, *Glyptocystites penniger*, Eichw., *Chætetes petropolitana*, *Polypora furcata*, Eichw., *Thamniscus bifidus*, Eichw., &c.

Our stage C 2 corresponds very fairly to the *Chasmops*-limestone of Scandinavia, occurring in Oeland, Westrogothia, and Norway.

C 3, *Itfer Beds.*

The stage C 3 I have distinguished only at a few localities, principally at Itfer, north of Wesenberg in Esthonia. The fauna is nearly the same as in C 2, but there are found some peculiar Trilobites, as *Sphærocoryphe Huebneri*, mihi, and *Chasmops Wrangeli*, mihi. Besides these, some forms belonging to the stage D, for instance *Mastopora concava*, Eichw., begin to appear. It is an intermediate stage of about 20–30 feet in thickness, and consists of a hard limestone with siliceous concretions, like the lower strata of stage D.

Stage D, *or Jewe Zone.*

The stage D, or the Jewe zone, is very characteristic of our Silurian system: it can be traced on the map from Gatschina (south of St. Petersburg) as far as Spitham at the north-western angle of Esthonia. In the western part of our Silurian I have been able to distinguish two subdivisions, the Jewe zone and the Kegel zone; but in the east, in the Government of St. Petersburg (principally along the Baltic railroad), I could see only the uppermost. Both subdivisions together may reach a thickness of perhaps 100 feet, principally in the east, where, at the railroad-station Jelisawetino, an artesian well, beginning in the upper part of D, did not strike the Glauconite Limestone, B 2, even at a depth of 200 feet.

The lower part of the stage D (the true Jewe zone) consists of siliceous marly limestone, the shells of fossils being very often silicified. Some fossils of the underlying stage C still occur, *e. g.* *Echinosphærites aurantium*, *Orthisina Schmidti*, Pahlen, *Orthoceras vertebrale*, Eichw. But the leading fossils are *Cheirurus pseudohemicranium*, Nieszk., *Hemicosmites extraneus*, Eichw., *Mastopora concava*, Eichw., and various conical casts (my memoir p. 33, fig. 6), undoubtedly of organic origin, but not yet clearly interpreted. The upper stage of D (the Kegel zone) is more marly (not siliceous), and is very rich in fossils, for example:—*Lichas deflexa*, Ang., *L. illænoides*, Nieszk., *Chasmops bucculenta*, Sjögr., *Strophomena Asmusi*, Vern., *Orthisina anomala*, Schloth., *Cyclocrinites Spasskii*, Eichw., &c. Both stages together are very rich in *Chasmops* (6 sp.), and have a great variety of Bellerophons and Lamellibranchiata. The fauna of the stage D has not yet been well studied. In Scandinavia and the British Islands, as well as in North America, no unequivocal representatives of our stage are found; yet the *Trinucleus*-schists of Sweden may probably be regarded as such. At the bottom of the Baltic sea, however, the Jewe zone may spread much further west, as in the island of Oeland and in the plains of North Germany many fossils belonging to this stage have been found in the Drift-deposits.

Stage E, *or Wesenberg Zone.*

The next zone E, the Wesenberg zone, begins on the east of the Narowa river at the river Pljussa, and can be traced west through the whole of Esthonia in a direction parallel to the Jewe zone. This

stage E consists of hard yellowish limestone, intercalated with marls, and is of a lesser thickness than the foregoing stage, never more than about 30 feet. The fauna is intermediate between the stages D and F, and shows clearly some relations to the English Caradoc and the American Trenton groups. In the frequent occurrence of *Leptæna sericea*, Sow., and *Strophomena deltoidea*, Conr., some corals, as *Favosites*, sp., and *Streptelasma*, sp., and Gasteropoda, such as *Murchisonia insignis*, Eichw., it shows near relations to the stage F; while other forms, such as *Cyclocrinus Spasskii*, Eichw., and *Orthis testudinaria* connect our stage with the foregoing stage D. In the same way the upper part of the Jewe stage (the Kegel stage) shows relations both to the lower part of the Jewe stage and to the Wesenberg stage (E), and serves to prove that, as I said before, there has not been any distinct interruption or break in the evolution of animal life during the formation of our Lower Silurian or Ordovician sytem. The characteristic Trilobites of the Wesenberg zone are *Phacops Nieszkowskii*, mihi, *P.* (*Chasmops*) *wesenbergensis*, mihi, *Encrinurus Seebachi*, mihi, *Cybele brevicauda*, Ang., *Lichas Eichwaldi*, Nieszk., *Isotelus*, sp., some of them passing over also to the lower strata of the stage F.

In Scandinavia our stage E is not clearly represented. In that region, as during the formation of the Jewe stage, slaty rocks with *Trinucleus*- and *Graptolite*-schists were deposited. I have already pointed out that the general character of the fauna of our Wesenberg zone allows us to compare our strata with those of the Caradoc or Bala group of England and the Trenton of North America.

Stage F. *Lyckholm and Borkholm Zones.*

Stage F (the uppermost of our Lower Silurian) is very rich in fossils, and very important also as affording means of correlating our rocks with foreign Silurian strata. With us it is restricted to Esthonia, and begins in the east near the Peipus Lake. It can be traced westward not only over the whole of the mainland of Esthonia, but also over the peninsula of Nuckö, and the island of Worms and the northern part of Dago. I formerly separated this stage into two zones, the Lyckholm zone (2 *a*) and the Borkholm zone (3). They are, however, so nearly allied in their faunas that I cannot separate them at present as distinct stages, but regard them rather as representing two subdivisions, the Lyckholm zone (F 1), and the Borkholm zone (F 2). The former consists of grey and yellow limestones and marls (often dolomitic); the latter of hard white coral-limestone. Both stages together may attain a thickness of 100 feet. The fauna of both subdivisions is very rich, the richest of all our Silurian stages, just as in the corresponding middle Bala group (Sedgwick) of Britain. The corals appearing in the foregoing stage are richly developed; most of the Upper Silurian genera are represented already; but the species are for the greater part different. The other classes are also very rich in species, namely the Gasteropoda, Cephalopoda, Acephala, Brachiopoda, and Bryozoa. There are also a

good many Encrinites; but the species are for the most part not yet defined. The Trilobites are restricted in number, and by no means so numerous as in the stages B and C. Several genera and subgenera have their last representatives in this stage, such as *Asaphus*, *Cybele*, *Chasmops*, *Pseudosphærexochus*, and others.

This stage is very well represented in other Silurian countries, in Sweden by the *Leptæna*-limestone of Dalarne; in Norway by the Gasteropod-limestone (Brögger) of Porsgrund and Brewig; in Britain by the Caradoc sandstone, and the Coniston and Craighead limestones; in America by the Trenton and Hudson groups. The Swedish *Leptæna*-limestone at the Osmundsberg in Dalarne (I visited that locality) seems to me perfectly identical with our white Borkholm limestone; and I must regard it as formed at the same time in the same ocean. The following list of identical fossils may possibly prove the correctness of my opinion:—*Cheirurus* (*Pseudosphærexochus*) *conformis*, Ang., *Sphærexochus angustifrons*, Ang., *Cybele brevicauda*, Ang., *Harpes Wegelini*, Ang., *Bronteus laticauda*, Ang., *Primitia brachynotha*, mihi, *Orthoceras fenestratum*, Eichw. (*funiforme*, Ang.), *Leptæna Schmidti*, Törnq., *L. luna*, Törnq., *Discina gibba*, Lindstr., *Propora conferta*, E. & H., *Heliolites dubius*, mihi, *Syringophyllum organon*, Linn., and many others. I cannot agree with some of the Swedish geologists and with Prof. Lapworth in regarding the *Leptæna*-limestone as Upper Silurian, because of its association (the stratigraphical conditions are not quite clear yet, according to Törnqvist) with the *Retiolites*- and *Lobiferus*-schists, which are said to correspond to British strata of Upper Silurian age. Of the British Bala group I may mention the following identical or nearly allied species in our stage F:—*Phacops* (*Chasmops*) *macroura*, Salt., not Sjögr. (the Cat's-head Trilobite), very near to our *T. Eichwaldi*, mihi, *Cheirurus octolobatus*, M'Coy, allied to our *C. conformis*, Ang., *Encrinurus multisegmentatus*, Portl., *Sphærexochus angustifrons*, Ang. (according to Törnqvist), *Calymene senaria*, Conr., *Bellerophon bilobatus*, Sow., *Pleurorhynchus* cf. *dipterus*, Salt., *Strophomena expansa*, Sow., *Orthis vespertilio*, Sow., *O. insularis*, Eichw., *O. fissicostata*, M'Coy, *O. porcata*, M'Coy (*solaris*, v. Buch), *O. Actoniæ*, Sow. (*Oswaldi*, v. Buch), &c. The corals and some other classes are not yet accurately compared. The Norwegian black limestones mentioned before show a still greater affinity, for instance, in the large Gasteropoda *Holopea ampullacea*, Eichw., *Subulites gigas*, Eichw., *Murchisonia bellicincta*, Hall, and others. Prof. Brögger, I hope, will soon give us a detailed account of the Norwegian Lower Silurian as compared with the Russian, as in 1880 he visited our country and collected sufficient materials for that purpose. The Trenton and Hudson groups of America show also a very similar character in their fauna; and a more detailed explanation of the fossils of our stage F will enable us also to make a more detailed parallelization with the corresponding American strata.

UPPER SILURIAN (*Silurian*, Sedgw.).

Our Upper Silurian (Silurian, *Sedgw.*) is very distinctly separated

from the Lower Silurian; no intermediate group like the English Llandovery can be recognized. There is a clear break with us in the development of organic life, notwithstanding the fact that the physical conditions remain the same; for the Upper Silurian strata consist of limestones and marls, like those of the Lower Silurian. At many places with us the lowest Upper Silurian, stage G, is observed in immediate contact with the highest Lower Silurian, F; but nowhere can there be any doubt concerning the geological age of these unvarying deposits. The same seems to be the case in Sweden. The island of Gothland shows a very full series of the Upper Silurian, but the Lower Silurian is entirely absent on that island; while, on the other hand, there are no traces of the Upper Silurian in Oeland. In Dalecarlia, as before mentioned, the relations of the Lower Silurian *Leptæna*-limestone to the *Lobiferus*- and *Retiolites*-Graptolithic schists are not yet clearly made out. In Norway the upper part of stage 5 of Kjerulf, described as being visible on the island of Malmö, belongs to our Upper Silurian, and the lower part to the Lower Silurian. Kjerulf did not separate the two divisions clearly; but to me, during my explorations in the neighbourhood of Christiania, it seemed easy enough to trace the limit between the Upper and the Lower Silurian, the line of division between them answering clearly to that in our own country. Prof. Brögger, I hope, will clear up all remaining difficulties.

The Upper Silurian of our country I divide into four stages, G, H, I, K, exactly corresponding to distinct stages or zones in the island of Gothland and, apparently, also to distinct stages in Norway, near Christiania. Compared with England, the lower stages G and H cannot be strictly correlated; but the upper ones (I and K) I regard without hesitation as corresponding respectively to the Wenlock and Ludlow groups.

The stages G and H are nearly allied to each other; both of them are characterized by peculiar species of smooth (not ridged) *Pentameri*, the former by *P. borealis*, Eichw., the latter by *P. esthonus*, Eichw. Both stages together may correspond also to the American Clinton group. As to the fauna, the corals and Trilobites are nearly the same in both groups, the common Upper Silurian Trilobites, *Calymene Blumenbachii*, *Encrinurus punctatus* and *Proëtus concinnus*, passing unaltered through the three stages G, H, and I. The characteristic fossils of the different Upper Silurian stages are the Brachiopoda, as already pointed out in Gothland by Prof. Lindström, and also the *Leperditiæ*, as I endeavoured to prove in my memoir on the Silurian *Leperditiæ* of Russia and neighbouring countries (St. Petersburg, 1873). The Gasteropoda and Acephala of the stages G and H are not yet fully examined.

Stage G. *Substage* G 1, *Jörden Beds.*

The stage G (zones 4 and 5 of my former publications) can be subdivided into three substages. The first of these, the Jörden zone, G 1, consists of thin calcareous flagstones and marls, and may

have a thickness of 20 to 30 feet. It can be traced along the northern boundary of our Upper Silurian, from near the Peipus Lake at Pastfer as far as the island of Dago; there the localities Kallasto and Helterma belong to this stage, while the small island of Wohhi is still Lower Silurian (F 2). The characteristic fossils are *Leperditia Hisingeri*, mihi, *Orthis Davidsoni*, Vern., *Strophomena pecten*, Linn., *Leptocœlia Duboisi*, Vern., *Rhynchonella affinis*, Vern., *Dinobolus Davidsoni*, Salt.

Substage G 2, *Borealis Bank.*

The next substage, G 2, consists almost entirely of agglomerated shells of *Pentamerus borealis*, Eichw. It forms a zone, wider in the east and narrower in the west, from near the Peipus as far as Hapsal, on the coast. Its thickness amounts to 40 feet. Some corals are mixed with the *Pentameri*. In the east it is not possible to find both valves together; but in the west the shells are not so thickly crowded, but not more than a few wholly preserved specimens have been obtained. In the island of Dago the *Pentamerus* loses its predominant character, and near Kallasto specimens of it are found dispersed among corals and other fossils of the stage G 1.

Substage G 3, *Raiküll Beds.*

The substage G 3, or Raiküll zone, occupies a rather large zone in Northern Livonia and South Esthonia. It consists of coral reefs and flagstones; its thickness may attain perhaps 100 feet. Most fossils are the same as in G1; but *Leperditia Hisingeri* becomes scarcer, and is replaced by *L. Keyserlingi*, mihi, found near Raiküll, the estate of the Count A. Keyserling, at which place the zone G 3 is best exposed. Of Trilobites, besides the common forms mentioned above, we may name *Phacops elegans*, Sars & Boeck (characteristic also of the corresponding stages in Scandinavia). The limestone is mostly very hard and often dolomitic, so that the fossils have not been as yet studied sufficiently.

Stage H, *or Pentamerus-esthonus Zone.*

The stage H is our upper *Pentamerus*-zone (6 of my former publications); it occupies also a large area south of G, and can be traced from Talkhof near Dorpat to the west end of Esthonia near Hapsal. In the east, dolomites prevail; in the west, grey coral-limestones with numerous specimens of *Pentamerus esthonus,* Eichw. The specimens are not so crowded together as in the *Borealis*-bank (G 2), and therefore well preserved examples are not scarce. The typical *Leperditia* of this stage is *L. abbreviata,* mihi (formerly regarded by me as a variety of *L. Hisingeri*, mihi, or *Schmidti*, Kolm.). Of other fossils, besides numerous corals, such as *Syringopora bifurcata*, Lonsd., *Favosites gotlandicus,* and at least five species of *Halysites*, there occur already some forms of the next stage I:—*Bumastes barriensis*, Sil. Syst., *Orthoceras canaliculatum*, Sow., *Strophomena euglypha*, Sow., *Spirifer radiatus,* Sow., and the typical *Atrypa reticularis,* Linn.

In Sweden our stages G and H are distinctly represented on the island of Gothland—the Wisby group, determined by Lindström and myself, representing our stage G, and the lower part of the Middle Gothland, characterized by *Pentamerus esthonus* and the typical *Leperditia baltica*, His., our stage H. In Norway I found both our stages on the island of Malmö, in the Bay of Christiania. On the eastern side of that island (still regarded by Kjerulf as belonging to the Lower Silurian, stage 5 *b*) I collected *Leperditia Hisingeri*, *Phacops elegans*, *Strophomena pecten*; on the western side I met with Kjerulf's stage 6, with *Pentamerus esthonus* and *Leperditia baltica,* as in the Middle Gothland. The comparison of both our stages G and H with British ones is rather difficult. In Britain the May-Hill Sandstone and Woolhope Limestone, with the Wenlock Shale, may be regarded as corresponding deposits. But the typical English *Pentamerus oblongus*, Sow., seems to be different from our and the Scandinavian species, both in a zoological and stratigraphical point of view, although Mr. Davidson has united our *P. esthonus* with *P. oblongus*. The former is much larger and always trilobed in front; it occurs with us and in Scandinavia in a geological horizon nearly allied to the English Wenlock Limestone; while *P. oblongus*, in England, belongs to the very bottom of the Upper Silurian, the May-Hill or Upper Llandovery group. On the other hand the large *Pentamerus* described and figured by Prof. J. Hall, from the Clinton group of America, as *P. oblongus*, seems to be very nearly the same as our *P. esthonus*; and so the general correlation of our stages G and H with the American Clinton group would present no difficulties, as even the other fossils seem partly to be identical.

While in England we cannot observe any stages strictly corresponding to our zones G and H, yet in the far north, in the Petschora country, and in Eastern Siberia, we find exactly corresponding representatives of the above-mentioned stages. In Eastern Siberia, between the rivers Wilni (affluent of the Lena) and Olenek, there are Upper Silurian limestones, recognized by Meak and Czekanowski, with *Calymene Blumenbachii*, *Phacops elegans*, *Strophomena pecten*, *Leptocœlia Duboisi*?, and the new *Leperditia wilniensis*, exactly the same as the limestones of our Jörden stage (G 1); while on the lower Tunguska river, near Turnschausk, Czekanowski found coral-limestones with a *Pentamerus* very nearly representing our *P. esthonus*. In 1846, Count Keyserling had already described Silurian limestones on the Waschkina river, on the Arctic Ocean (near the mouth of the Petschora river, west of the Ural Mountains), with *Pentamerus samojedicus* (nearly allied to *P. esthonus*), typical *Leperditia marginata*, and common Upper Silurian corals, which also may be regarded as representing our stage H, or Kjerulf's stage 6.

Stage I, *or Lower Oesel Zone.*

The stage I (formerly 7) occupies the south-west corner of our Silurian territory on the mainland of Esthonia, and a narrow space along the cliff on the north coast of the islands Mohn and Oesel.

This stage is doubtless a representative of the typical Wenlock Limestone of England. A long list of identical fossils might be adduced; for instance, *Orthoceras annulatum*, Sow., *O. canaliculatum*, Sow., *Euomphalus funatus*, Sow., *sculptus*, Sow., *discors*, Sow., *Turbo striatus*, Sow., *Spirifer cyrtæna*, Dalm. (*radiatus*, Sow.), *S. crispus*, Dalm., *Orthis rustica*, Sow., *O. elegantula*, Sow., *Leptæna transversalis*, Sow., *Cornulites serpularius*, Schl., and the common Trilobites and corals. In the Swedish island of Gothland the corresponding stage is the upper part of the Middle Gothland zone, and in Norway the stage 7 of Kjerulf. In America, as is well known, the Niagara Limestone is the equivalent. In our stage I, dolomites prevail, and so we do not possess so many good localities for collecting fossils as in Gothland. The best locality with us is St. Johannis, on the north shore of Oesel. The thickness of the stage may attain 60 feet.

Stage K, *or Upper Oesel Zone.*

The stage K can as easily be correlated with the Ludlow group of England as the stage I with the Wenlock. It occupies the southern and western part of the island of Oesel, and may attain a thickness of perhaps 50–60 feet. Within its limits can be distinguished two different contemporaneous facies passing over into each other. On the south coast, and on the peninsula of Sworbe (the Kangatoma and Ohhesaare Pank), grey limestones and marls predominate, with *Spirifer elevatus*, His., *Atrypa prunum*, His., *Retzia Salteri*, Dav., *Rhynchonella nucula*, Sow., *Chonetes striatella*, Dalm., *Beyrichia tuberculata*, Klöd., *B. Wilkinsiana*, Jones, and quantities of a large form of *Ptilodictya lanceolata*, Lonsd., and several *Tentaculites* (*inæqualis*, Eichw., and *curvatus*, Boll). The large *Pterinea retroflexa* and *reticulata* and *Grammysia cingulata*, His., are also common in some places. In Sworbe there are also found numerous specimens of *Onchus*, and small scales of *Pachylepis*, Pand. (nearly the same as *Thelodus parvidens*, Sil. Syst.). All the fish-remains were described in 1856 by the late M. Chr. Pander.

To the north-west of Arensburg, in the interior, and on the western shore of the island, the other facies is developed, yellow limestones with *Leperditia phaseolus*, His., *Orthoceras imbricatum*, Wahl., *Spinigera didyma*, Dalm., *Chonetes striatella*, Dalm., *Murchisonia cingulata*, His., *Lucina prisca*, His., *Goniophora cymbæformis*, His., *Syringopora reticulata*, His., and others. These yellow beds repose on dolomitic flagstones, in most places entirely devoid of fossils, but furnishing near the west coast of Oesel, at Rotziküll, a highly interesting Eurypterid fauna, exactly corresponding to that of the famous British locality of Lesmahago and the American Waterlime group. I am now preparing a detailed description of the fossil crustaceans of this locality, and may mention here the results of my latest inquiries. The most frequent fossil is *Eurypterus Fischeri*, Eichw. (formerly called *E. remipes*, Dek., by Dr. Nieszkowski). I believe that nowhere can be found such abundant and such completely preserved specimens of this interesting genus. I have

been collecting at Rotziküll upon several occasions, and I have now brought together such a large mass of materials, that nearly all the small details of the structure can be explained thereby. Nieszkowski, in his paper on *Eurypterus* (Dorpat, 1858), assumed six free thoracic plates; I cannot now detect more than five, but this number is indubitable; and I cannot agree with Dr. H. Woodward, who, according to Prof. J. Hall's detailed but insufficient description, does not assume more than *one* of such thoracic plates. Certainly there has been a misconception on the part of Nieszkowski as to the central appendage; but the positive existence of five free plates (corresponding to six in *Limulus*) I shall be able to prove by numerous figures, taken from original specimens, and by a detailed description.

A second discovery is a large *Pterygotus*, an intimate ally of *P. gigas*, Salt., but probably a new species. No wholly preserved specimens are found; but I possess all necessary details, with the exception of the telson. Of peculiar interest also are three species of the genus *Bunodes*, Eichw., namely *B. lunula*, Eichw., *B. rugosus*, Nieszk., and *B. Schrenckii*, Nieszk., sp., (*Exapinurus Schrenckii*, Nieszk.), and *Pseudoniscus aculeatus*, Nieszk. Both genera are perhaps most nearly allied to the British genus *Hemiaspis*, Salt., as I was kindly convinced by Dr. H. Woodward, on my visit to the British Museum in 1875. Dr. Woodward enumerates *Hemiaspis* among the Eurypterida; but I believe that the three genera *Hemiaspis*, *Bunodes*, and *Pseudoniscus* should form a distinct family intermediate between Eurypterida and Trilobites. The want of strongly developed swimming-feet and other appendages on the lower side of the head, the distinct trilobation of the thorax, and the chemical constitution of the carapace (which is always destroyed in dolomites, like that of Trilobites, while the chitinous covering of Eurypterida even in dolomites is beautifully preserved) show the difference of the Hemiaspida and Eurypterida, and the near relation of the former to Trilobites, with which group the genus *Bunodes* was formerly classed by Eichwald, in his 'Lethæa Rossica.' Besides the above-named crustaceans, I have yet to mention a large form of the *Ceratiocaris*-group, the new genus *Cardiocaris*, with a large cordiform dorsal shield, somewhat similar to the Carboniferous *Dithyrocaris*, Scouler. Of other classes in the *Eurypterus*-Dolomite there occur an *Orthoceras*, *O. tenue*, Eichw., with the shell destroyed, and two interesting Cephalaspidian fishes, *Thyestes verrucosus*, Eichw., and *Tremataspis Schrenckii*, Pand., mihi, formerly figured and described by me in 1866, in the 'Verhandlungen' of the St. Petersburg Mineralogical Society. The *Eurypterus*-strata are overlain by thin marly flags filled with the typical English *Platyschisma helicoides*, Sow., together with numerous specimens of *Leperditia phaseolus*, His. (*Angelini*, mihi), and small fish-scales of the genus *Cœlolepis*, Pand., and other minute fish-remains. Then follow the before-mentioned yellow limestones with *Murchisonia cingulata*, *M. didyma*, and *Chonetes striatella*. In the island of Gothland the same species of *Eurypterus* is also met at the base of the uppermost Silurian stage, near Oestergari, and the same is also the case in Podolia on the Dniester.

Our stage K fully corresponds to the uppermost stage of Gothland (South Gothland according to Lindström and myself), to the highest Silurian stage in Norway (8 of Kjerulf), and to the Onondaga salt-group and the Waterlime group, together with the Tentaculite-limestone of New York.

Relation of Silurian and Devonian Strata.

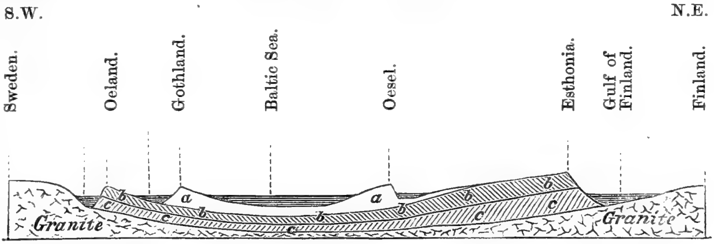
With us, as in Scandinavia and in England, the Silurian system is completed by our stage K and its corresponding strata already described. The Helderberg group of America, as well as the stages F, G, and H of Barrande, I should rather prefer to call Devonian, in accordance with the views of Dr. Kayser. To the same lowest Devonian may belong also the so-called Upper Silurian of the Ural and Altai Mountains, with ribbed *Pentameri* and several Trilobites and Brachiopoda, reminding us of analogous forms of the uppermost Bohemian stages. In England as well as in Podolia and Galicia on the Dniester the uppermost Silurians pass gradually over into beds containing Cephalaspida, Pteraspida, and some new Eurypterida. It is difficult to decide the question whether these *Cephalaspis*-beds should also be named Devonian, or whether it would be more convenient to unite them with the uppermost Silurian, in which the above-named groups of Cephalaspida, Pteraspida, and Eurypterida are all known to begin.

With us, in the Baltic Provinces, we have no traces of the above-mentioned passage-beds or the lowest Devonian. The Silurian strata are covered unconformably by the Old Red Sandstone, with *Coccosteus*, *Asterolepis*, *Bothriolepis*, *Homosteus*, and *Heterosteus*. The Devonian is superposed upon the Lowest Silurian (the Orthoceratite-limestone) in the east, on the river Sjas, and covers the younger Silurian strata in turn as we advance to the west. Thus at Pawlawsk it covers the Echinosphærite-limestone (C), near Gatschina the Jewe stage (D), on the Narowa the Wesenberg stage (E), and in the west of Livonia, at Torgel, near Pernan, the stage H is covered by Devonian sandstones with fish-remains and the curious coaly stems of the still problematical *Aulacophycus striatus*, Eichw., regarded by Eichwald as an Alga, but having a coniferal structure, according to Göppert. Our Devonian rocks do not anywhere cover immediately the stage K; and the two systems must be regarded as entirely independent of each other throughout the whole extent of our eastern Baltic territory; while the three divisions of the Silurian (according to Murchison and Barrande), or the Cambrian and Silurian of others, or the Cambrian, Ordovician, and Silurian of Prof. Lapworth, form one regular coherent series of strata apparently deposited in one and the same ancient ocean, to which series, so far as our country is concerned, I would prefer to attribute the name of a "System."

The Swedish Silurian strata on the west side of the Baltic correspond so accurately to ours on the east side, according to the inclination of strata and the formation of the sea-shore cliff, that I found it possible to reconstruct a section through the Baltic, from Wiborg

in Finland to Kalmar in Sweden. The section is delineated on page 59 (F 8) of my memoir, and may be repeated at this place.

Ideal Section of the Silurian Formation between Wiborg in Finland and Kalmar in Sweden.



a. Upper Silurian. *b.* Lower Silurian. *c.* Cambrian.

Concluding Remarks.

In the foregoing pages I have merely given an account of the stratigraphical part of my memoir. I may now be permitted to make also a few remarks upon its palæontological contents. Commencing in the year 1853, but delayed by interruptions caused by Siberian expeditions from 1859–63 and 1866, and by a long illness from 1868–70, I have spent the largest part of each summer in studying our Silurian system and in collecting fossils from it. I have founded a separate Silurian collection in the provincial museum of Reval, where I have left sufficient room to place all the rich materials brought together every summer from the various points of our Silurian territory. In addition, Silurian fossils in the remaining museums of our country are at my disposal, for instsnce, the collection of Volborth, in the Museum of the St. Petersburg Academy, the collection of Eichwald, presented to the St. Petersburg University, the collection of Pander in the St. Petersburg School of Mines, the collections at Dorpat in the University Museum and the Museum of the Natural-History Society, &c. Not only so, but I have visited several times the museums of Sweden and Norway, and the most important Silurian localities in those countries. In 1875 I had also the opportunity of studying for a few days the British collections. Moreover, I have studied divers collections of Silurian erratics in the museums of Northern Germany, from which region many species have been described which have not hitherto been found in their original beds. In this way it is possible for me to make full use at one time of all the different collections from our Silurians, brought together at different times by divers collectors; and it is my purpose to perform the task of describing and figuring, in an accurate way, all our Silurian fossils, if my life be spared.

The memoir I have just completed contains the descriptions and figures of three families of Trilobites, the Phacopidæ, Cheiruridæ, and Encrinuridæ, altogether 60 species. The number of all our Trilobites will be about 150 species, of which only 15 are Upper Silurian; all the rest are Lower Silurian. The next part of my

monograph will comprise the Lichadæ, Calymenidæ, Acidaspidæ, and some other small groups, leaving the largest group, the Asaphidæ (about 40 species), to the third and last part. I try to follow every genus through the different stages and to investigate the changes undergone by it during the development of Silurian life.

The accompanying map (Pl. XXIII.) is constructed on the scale of 1 : 1,500000, the same as that proposed by the Geological Congress for the new international geological map of Europe. I have marked on the map not only the three great divisions of our Silurian, but also the zones from A to K, and some of the subzones, so far as these subzones can be traced. The names on the map represent some of the most important geological localities.

List of the Described Species of Phacopidæ, Cheiruridæ, and Encrinuridæ of the Silurian Rocks of the Baltic Provinces, arranged in accordance with Salter's Monograph of British Trilobites.

	B.		C.			D.	E.	F.	G.	H.	I.	K.	Abroad.
	2	3	1	2	3								
I. PHACOPIDÆ.													
Genus PHACOPS, *Emmr.*, *Salt.*													
Subgenus *Phacops*, Salt.													
1. Phacops elegans, *Ss. et Boeck* (P. Stokesi, *Edw.* pt.)									*	*			Gothland, Norway, E. Siberia (England ?).
Subgenus *Acaste*, Salt													
2. P. Downingiæ, *Murch.* (P. breviceps, *Ang.* See Lindström, the syn. omitted in the text of the memoir)												*	Gothland, England, Podolia.
Subgenus *Pterygometopus*, mihi.													
Supports of the frontal lobe crossed by the facial suture. The type is *P. sclerops*, Dalm. English species are *P. alifrons*, Salt., and perhaps also *P. llanvirnensis*, Hicks.													
3. P. sclerops, *Dalm*	*	*											Sweden (*Orthoceras*-limestone).
4. P. trigonocephala, *mihi*		*											Sweden (with the former).
5. P. Panderi, *mihi*			*										
6. P. exilis, *Eichw*			*	*									
7. P. lævigata, *mihi*						*							Prussia, erratics.
8. P. kuckersiana, *mihi*				*									
9. P. kegelensis, *mihi*						*							Prussia, erratics.
10. P. Nieszkowskii, *mihi*							*						Prussia, erratics.
Subgenus *Chasmops*, M'Coy.													
11. P. ingrica, *mihi*			*										
12. P. nasuta, *mihi*			*										
13. P. præcurrens, *mihi*			*										

	B.		C.			D.	E.	F.	G.	H.	I.	K.	Abroad.
	2	3	1	2	3								
14. P. Odini, *Eichw.* (very near P. conicophthalma, *Ss. et Boeck*)	...	...	*	*	...	...	...	...	...	...	...	...	Sweden ?, erratics in N. Germany.
—— var. itferensis.	...	...	...	...	*								
15. P. marginata, *mihi*	...	...	...	...	*	*	...	...	...	...	...	...	Erratics in N. Germany.
16. P. Wenjukowi, *mihi*	...	...	...	...	...	*							
17. P. bucculenta, *Sjögr.*	...	...	...	...	...	*	...	...	...	...	...	...	Erratics in Oeland and N. Germany.
18. P. Wrangeli, *mihi*	...	...	...	...	*								
19. P. maxima, *mihi*	...	..	...	...	...	*	...	...	...	...	...	...	Erratics, N. Germany.
20. P. mutica, *mihi*	..	...	...	...	...	*							
21. P. brevispina, *mihi*	...	...	...	...	...	*							
22. P. wesenbergensis, *mihi*	...	...	...	...	...	...	*	*	...	...	...	...	Erratics, Prussia.
23. P. Eichwaldi, *mihi* (very near P. macroura, *Salt.*, not *Sjögr.*, or pelinus, *Salt.*)	...	...	...	...	...	...	...	*	...	...	...	...	Erratics, N. Germany.
Phacopidæ	1	2	6	3	3	8	2	2	1	1	...	1	
II. CHEIRURIDÆ.													
Genus CHEIRURUS, *Beyr.*													
Subgenus *Cheirurus*, Salt.													
24. Ch. ornatus, *Dalm.*	*	*	...	...	..	...	...	...	...	...	...	...	Sweden (*Orthoceras*-limestone).
25. Ch. ingricus, *mihi*	...	*											
26. Ch. exsul, *Beyr.*	...	...	*	...	...	...	...	...	...	...	...	...	Sweden (Oeland and Dalarne), erratics in N. Germany.
—— subsp. macrophthalmus, *Kut.*	...	...	*										
—— —— gladiator, *Eichw.*	...	...	*										
27. Ch. spinulosus, *Nieszk.*	...	...	...	*									
28. Ch. glaber, *Ang.*	...	...	...	...	...	...	...	*	...	...	...	...	Sweden (Dalarne).
Subgenus *Cyrtometopus*, Ang. 11 segments.													
29. Ch. clavifrons, *Dalm.*	*	*	...	...	...	...	...	...	...	...	...	...	Sweden, Norway (*Orthoceras*-limestone).
30. Ch. affinis, *Ang.*	...	*	...	...	...	...	...	...	...	...	...	..	Sweden (*Orthoceras*-limestone).
31. Ch. Plautini, *mihi*	...	...	*	*	...	...	...	...	...	...	...	...	Erratics in Prussia.
32. Ch. Rosenthali, *mihi*	...	...	...	...	...	*							
33. Ch. aries, *Eichw.*	...	...	*	...	...	...	...	...	...	...	...	...	Norway.
34. Ch. pseudohemicranium, *Nieszk.*	...	...	...	...	...	*	...	...	...	...	...	...	Erratics in Prussia.
—— var. dolichocephala, *mihi*	...	...	...	*	*								
Subgenus *Sphærocoryphe*, Ang. 9–11 (?) segments to the body.													
35. Ch. cranium, *Kut.*	...	...	*	*									
36. Ch. Huebneri, *mihi*	...	...	...	...	*								
37. Ch. granulatus, *Ang.*	...	...	...	...	...	...	*	*	...	...	...	...	Sweden (Delarne).

	B.		C.			D.	E.	F.	G.	H.	I.	K.	Abroad.
	2	3	1	2	3								
Subgenus *Pseudosphærexochus*, mihi.													
12 segm. to the body; pleuræ nearly smooth, without impressions. Pygidium octolobate. Type *Sphærexochus hemicranium*, Kut.: of English Trilobites, perhaps *Ch. octolobatus*, M'Coy, belongs to this subgenus.													
38. Ch. hemicranium, *Kut.*	...	...	*										
39. Ch. Pahnschi, *mihi*...........	...	...	...	...	...	*							
40. Ch. Rœmeri, *mihi*	...	...	...	...	...	...	...	*	...	...	...	...	Erratics in N. Germany.
41. Ch. conformis, *Ang.*	...	...	...	...	...	...	...	*	...	...	...	...	Sweden (Dalarne).
Subgenus *Nieszkowskia*, mihi.													
12 segments to the body, pleuræ with a row of impressions. Pygidium 4-lobed. Type *Sphærexochus cephaloceros*, Nieszk., *Cheir. Vulcanus*, Bill.													
42. Ch. tumidus, *Ang.*	...	*	*	...	...	...	...	...	...	...	...	...	Sweden (*Orthoceras*-limestone).
43. Ch. cephaloceros, *Nieszk.* ...	...	...	*	*									
44. Ch. variolaris, *Linnarss.* ...	...	...	*	*	...	...	...	...	...	...	...	...	Sweden (*Chasmops*-limestone). Erratics in Prussia.
Genus Sphærexochus, *Beyr.*													
45. S. angustifrons, *Ang.*	...	...	...	...	...	...	...	*	...	...	...	...	Sweden (Dalarne), England.
Genus Amphion, *Pand.*													
46. A. Fischeri (*Eichw.*)	...	*	...	...	...	...	...	...	...	...	...	...	Sweden *Orthoceras*-limestone.
Genus Diaphanometopus, *mihi* (near *Amphion*).													
47. D. Volborthi, *mihi*	...	*											
Cheiruridæ...........	2	7	10	6	2	3	1	5					
III. ENCRINURIDÆ.													
Genus Cybele, *Lov.*													
48. C. bellatula, *Dalm.*, (syn. Zethus verrucosus, *Pand.*, *Volb.*)	*	*	*	...	...	...	...	...	...	...	...	...	Sweden, Norway (*Orthoceras*-limestone).
49. C. revaliensis, *mihi*..........	...	...	*	*	...	...	...	...	...	...	...	...	Erratics in N. Germany.
50. C. rex, *Nieszk*..................	...	...	...	*	*								
51. C. Grewingki, *mihi*...........	...	...	...	...	...	*							
52. C. coronata, *mihi*	...	...	...	*									
53. C. Worthi, *Eichw.* (Zethus bellatulus, *Volb.*)	...	...	*										

	B.		C.			D.	E.	F.	G.	H.	I.	K.	Abroad.
	2	3	1	2	3								
54. C. affinis, *mihi*	...	...	*										
55. C. Kutorgæ, *mihi*	...	...	...	...	...	*	*						
56. C. brevicauda, *Ang.*	...	...	...	...	...	...	*	*	...	...	...	...	Sweden (Dalarne).
Genus Encrinurus, *Emmr.*													
57. E. obtusus, *Ang.*	...	...	...	...	...	...	...	...	...	...	...	*	Gothland.
58. E. punctatus, *Wahlb.*	...	...	...	...	...	...	...	...	*	*	*	*	England, America, Sweden, Norway, Podolia.
59. E. multisegmentatus, *Portl.*	...	...	...	...	...	...	...	*	...	...	...	...	Iceland, erratics in N. Germany.
60. E. Seebachi, *mihi*	...	...	...	...	...	...	*	*					
Encrinuridæ	1	1	4	3	1	2	3	3	1	1	1	2	
Next follows the genus *Lichas*, of which 22 species are already determined and drawn.	4	10	20	12	6	13	6	10	2	2	1	3	

EXPLANATION OF PLATE XXIII.

Fig. 1. Sketch Map of the Silurian (and Cambrian) Strata in the Eastern Baltic Provinces of Russia, St. Petersburg, Ingermanland, Esthonia, Livonia, and the Island of Oesel.

2. Section through the Western Coast-region of Esthonia, from Werder to Odensholm.

3. Section from Malla and Kunda in Esthonia, on the Gulf of Finland, to Talkhof, in Livonia. (From Prof. Grewingk's Geological Map of Esthonia, Livonia, and Courland.)

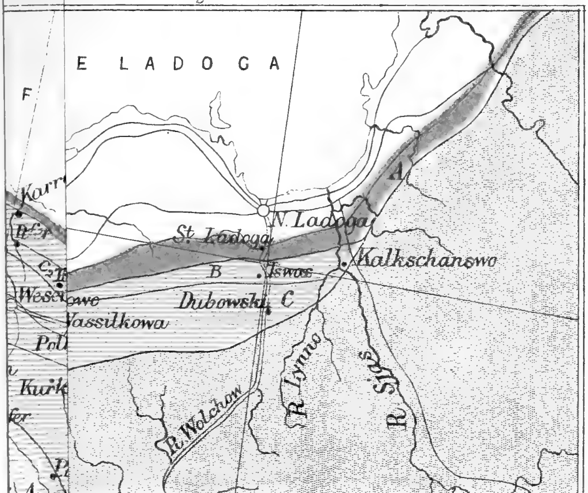
Discussion.

Prof. Hughes could not understand why the author should regard the whole as forming a continuous series, when he admitted a palæontological break at the top of Sedgwick's Cambrian, and the conformity might be local or accidental, as was commonly the case in this country.

Mr. Marr pointed out that the uppermost bed of group F had a fauna similar to that of the lower part of the Brachiopod shales of Sweden, and that certain blue shales of this series are not represented in Russia; consequently not only is there a palæontological break at this horizon, but also deposits found elsewhere are absent. The beds of group G are correlated with the May-Hill beds, and represent both the upper and lower divisions. In Russia, therefore, as in other areas, there is a break at the base of the May-Hill group. The line which the author draws between Primordial and Lower Silurian is drawn at the base of beds which he correlates with the *Ceratopyge*-limestone, the equivalent of the Tremadoc

beds. This line is drawn at a different horizon from that which is taken by English geologists. There is therefore only one widely spread break occurring in this group of rocks, and it is that separating the Cambrian System of Professor Sedgwick from Sir Roderick Murchison's Silurian System.

Dr. Hicks bore testimony to the great value of Dr. Schmidt's paper. He could see no reason for doubting the continuity of the whole series as maintained by Dr. Schmidt. It was impossible to believe that these stratigraphical breaks were universal, as Prof. Hughes and Mr. Marr seemed to suppose.



ig 1.

SILURIAN (AND CAMBRIAN)

BALTIC PROVINCES OF RUSSIA

ANLAND, ESTHONIA, LIVONIA

LAND OF OESEL.

IN 1,500,000

RIAN	UPPER SILURIAN G–K	DEVONIAN

LLA

PROF

4383

DANGERFIELD, LITH 22 BEDFORD S^T COVENT GARDEN.

Fig 1.

SKETCH MAP OF THE SILURIAN (AND CAMBRIAN) SYSTEM IN THE EASTERN BALTIC PROVINCES OF RUSSIA St. PETERSBURG, INGERMANLAND, ESTHONIA, LIVONIA AND THE ISLAND OF OESEL.

Fig 2.

SECTION THROUGH THE WESTERN COAST REGION OF ESTHONIA, FROM WERDER TO ODENSHOLM.

Fig 3.

SECTION FROM MALLA & KUNDA IN ESTHONIA ON THE GULF OF FINLAND TO TALKHOF IN LIVONIA. FROM PROF GREWINCK'S GEOLOGICAL MAP OF ESTHONIA, LIVONIA, & COURLAND.

DANGERFIELD, LITH 22 BEDFORD St COVENT GARDEN.

49. *The* GIRVAN SUCCESSION. By CHARLES LAPWORTH, Esq., F.G.S., Professor of Geology and Mineralogy, Mason Science College, Birmingham.—Part I. STRATIGRAPHY. (Read June 7, 1882.)

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I. Introduction.

1. *Lower Palæozoic Strata of Girvan and the Southern Uplands of Scotland.*

That portion of Scotland which lies to the south of the metamorphic area of the Highlands is composed of two very distinct physiographical regions—the plateau of the Southern Uplands, and the low-lying district of the central valley of Lanark and Midlothian. In all their grander features, physical, geological, and economical, these two regions are strikingly contrasted. The Upland region is an elevated tableland, with a smooth, flowing contour of alternate hill and dale; its grass-clad surface, almost destitute of arboreal vegetation, is devoted to pasturage, and supports but a scanty and sparsely scattered population. The surface of the Lowland region, on the other hand, is picturesquely diversified by steep hill-ranges, which are adorned with plantations of oak and fir, and enclose wide and fertile plains, highly cultivated, and inhabited by a numerous and wealthy population. Again, the Upland region is a land of *Lower* Palæozoic rocks, composed of an endless repetition of dingy greywackes and shales, which repeat the monotony of the surface in the sameness of their petrographical characters. The valley-region is, by contrast, a land of *Upper* Palæozoic strata, of sandstones, limestones, coal, and volcanic rocks, as diversified in their mineralogical features as is the picturesque scenery to which they have given origin. Finally, the Lower Palæozoic rocks of the Uplands may be traversed for miles without affording a trace of a fossil or an interesting mineralogical specimen; and only in one very limited locality are their minerals of the slightest economic value. The Upper Palæozoic strata of the great valley, on the other hand, are, alike in their fossils and minerals, among the most productive in the island.

From the eastern sea-board near Dunbar, across the entire breadth of Scotland to a point almost within sight of the North Channel, it may almost be said that this violent contrast in the structure and natural characteristics of the two regions is maintained unbroken. The huge grass-grown slope, with its softly undulating sky-line, which marks the northern margin of the Upland, rises upwards like the edge of a vast terrace, and looks out far and wide over the Lowland region to the northward, with its varied surface of hill and dale.

But at the south-western extremity of this marked boundary-line lies a district which it is impossible to assign satisfactorily either to the Upland or to the Lowland region. This is the beautiful district of Carrick—the land of Craigs—which forms the south-western division of Ayrshire, and is drained by the waters of Girvan and Stinchar. In its physiographical aspect this district partakes of the characters of both the Upland and the Lowland regions. Its higher grounds repeat the flowing, mound-like, grass-grown forms of the Upland hills, with the straggling village, the

remote pasture-farm, and the lowly sheiling of the shepherd. Its open valleys and less elevated grounds are those of the Lowland region, relieved by steep ridges clothed with copses of oak and fir, and sheltering fertile corn-lands and busy villages, inhabited by a population employed in mining and agriculture.

To a large extent this union of the diverse peculiarities of these two physical regions in one and the same area is owing to the fact that there is an alternation of the distinctive strata of the two regions within its limits—its more elevated portions being formed of Lower Palæozoic rocks, and its low-lying sections floored by faulted patches of the more diversified Upper Palæozoic strata. But, strange to say, the majority of the diversified strata of this Carrick district are of the same general geological age as the monotonous Lower Palæozoic rocks of the Uplands, and many of the more abrupt physical features of the district are actually due to the local peculiarities of those strata as here exhibited. It is, indeed, true that upon several horizons in its succession we meet with strata whose dingy colours, monotonous lithological characters, and utterly barren nature are identical with those of the generality of the Silurian rocks of the Uplands; but, as a rule, the Lower Palæozoic strata of the Carrick district are vastly different in all their characteristics from their Upland counterparts. In their petrographical features they are fully as diversified as are the Upper Palæozoic strata of the central valley; and this diversity in structure is accompanied by an astounding increase in the abundance and variety of their organic remains. Among the rocks of the Southern Uplands limestones are practically unknown, conglomerates and shelly sandstones are only occasionally present; the interminable succession of barren greywackes and shales is but rarely interrupted by the occurrence of an insignificant seam of black mudstone affording a few Graptolites. In the corresponding strata of Carrick, however, fossils of all the invertebrate classes, Hydroida, Actinozoa, Trilobita, Brachiopoda, and Cephalopoda, are more or less plentifully distributed throughout the entire succession, and, upon several horizons, even swarm in extraordinary profusion. Shelly sandstones and sandy grits, carbonaceous shales and Graptolitic mudstones occur in great force; limestone is developed to an extent unequalled elsewhere among the Lower Palæozoics of the south of Scotland; while the massive conglomerates and tumultuous boulder-beds attain a thickness and a geological importance as yet unparalleled in the Lower Palæozoic world.

In a further and yet more salient feature the rocks of this area are trenchantly contrasted with their counterparts of the Southern Uplands. In the Upland region, if we except the scattered trap-dykes and the intrusive granitic bosses of Cairnsmore and the Kells, igneous outbursts, either contemporaneous or subsequent, may be said to be unknown. In the west of the Carrick district, on the contrary, we find exhibited one of the most interesting igneous areas in Britain, whether we have regard to the diversified nature of its products, to their enigmatical mode of occurrence, or to

the ingenious and mutually destructive theories that have been framed respecting their manner of origin and their relationship to the aqueous strata in which they are enveloped.

The physical geologist and stratigraphist, repulsed by the unattractive features and non-fossiliferous character of the rocks of the Southern Uplands, has always turned to this Carrick district with sanguine anticipation. Convinced of the excessive difficulty and even uselessness of reducing the monotonous Upland strata to their natural order, he is the more readily persuaded that here, at least, is a region where his labours will be repaid with interest. Among rocks so varied and so attractive, and so prolific of fossils, the detection of the true key to the succession must surely be a delightful task, whose steps must be all easy and pleasurable, and whose end must be success.

Within the last thirty years the rocks of this district have been studied, in whole or in part, by many of the most successful British geologists—by J. C. Moore, Nicol, Sedgwick, Murchison, and Geikie; and they have been carefully mapped in detail by the officers of the Geological Survey. Their fossils have been collected in the field and studied in the closet by M'Coy, Salter, Wyville Thomson, Davidson, Etheridge, Nicholson, and by a host of minor palæontologists, past and present. They have been painfully tabled in catalogues and figured in monographs; and their more striking zoological types have long been classic in the palæontological world. In brief, a blaze of scientific light has been concentrated upon this little district, more intense and sustained than upon any other Lower Palæozoic area of equal extent in Britain. Nevertheless our knowledge of the true sequence and characteristic life-groups of the natural divisions of its fossil-bearing strata seems today as far off as ever. Of all the diverse theories of the succession held at present, officially and non-officially, there is not one that is not implicitly acknowledged to be vague, tentative, and unsatisfactory; while the most popular and best-supported theory of all, that of Murchison himself, has long been known to be incompatible not only with the physical evidences obtainable within the district itself, but with that special palæontological gradation which is now universally recognized among the corresponding Lower Palæozoic rocks all over the world.

The causes of this unsatisfactory result are not far to seek, and they are both physical and palæontological in their origin. Precisely as in the Lower Palæozoic rocks of the Uplands, the strata of the Carrick region are so convoluted by folds, and so intermingled by faults, that it is impossible to rely upon evidences of superposition derived from longitudinal sections traversing extended areas; and British geologists, trained in the less complicated Upper Palæozoic regions, have not hitherto found time or patience to work out the sequence in the only way in which success is possible, namely, painfully and elaborately, zone by zone, and bed by bed.

The frequent repetition of strata identical in lithological characters upon many distinct horizons in the vertical succession affected by

these folds has resulted in the confounding of beds vastly different in geological age. The numerous longitudinal faults which cut through the district along the strike of the beds have brought into unnatural juxtaposition strata widely separated in the true vertical series; and, even where the sequence is the natural one, the predominating inversion has forced the conscientious stratigraphist to give the physical testimony an erroneous interpretation.

The palæontological evidences, as they have been hitherto construed, have led to a confusion of opinion even more perplexing and disheartening. By far the larger proportion of the fossils recorded from this district have been obtained from a few limited areas, and at most from half a dozen different horizons, while all the intermediate and less fossiliferous strata have remained practically untouched. The unfortunate habit of collectors of grouping together fossils according to the area whence they were procured, instead of the individual stratum to which they belong, has here been carried to excess. We find in the same local list species elsewhere of Wenlock, Llandovery, Caradoc, and even of Llandeilo age, all tabled together as if they had been obtained from one and the same stratigraphical zone. This has had its inevitable result, not only in hiding from view the defective stratigraphy, but in casting ridicule and even odium upon palæontological testimony in general. Even Professor Ramsay, the former head of the Geological Survey, whose life has been mainly spent in the study of the Lower Palæozoic rocks, unable to reconcile the numberless discrepancies between the apparent sequence, palæontological and stratigraphical, as here developed and that worked out by himself in the regions of Siluria, has been driven to the conclusion that these enigmatical Scottish rocks belong to an episode of a date between that of the Bala and the Llandovery, unrepresented among the fossil-bearing rocks of the South of Britain.

Nor, until very recently, could any available light be brought to bear upon the difficulties which beset the study of the strata of Carrick, derived from testimony obtained among the Lower Palæozoic rocks that lie outside the district itself. The inevitable intermingling of the fossils of distinct zones in the tables of such classical works as Murchison's 'Siluria,' M'Coy's 'Palæozoic Rocks and Fossils,' Barrande's 'Système Silurien,' and in the publications of the Geological Survey, ran so fully in harmony with the supposed facts obtainable in Carrick, that no definite palæontological error was discernible of sufficient moment either to cast doubt upon the supposed physical sequence, or to stimulate inquiry into the less universally accepted theory of the intermixture in the same beds of so many distinct types of fossils.

But, within the last few years, a more detailed study of the minor groups of strata recognizable in the Lower Palæozoic rocks of Wales has been most successfully inaugurated by Dr. Hicks. The subsequent investigation of the correspondent strata of Scania and Dalarne by the Swedish geologists has resulted in proving to demonstration that, even in sediments of such contracted vertical

dimensions as are there developed, the change of life-type seems to have been strictly dependent upon the progress of geological time, the successive fossil assemblages differing in facies among themselves in proportion to the geological interval which separates them. These discoveries have thrown a new light upon the magnificent results long since obtained by Barrande in Europe, and by Hall and his brother geologists in America, and have led some of the more sanguine students of British Geology to hope that, not only would the grand rock-systems of Lower Palæozoic age on this side of the Atlantic admit of a rude parallelism in areas now widely separated geographically, but that even their formations, subformations, and more important zones of life might in time be synchronized with average accuracy, and an ascending geological scale be thus constructed comparable with that which has proved so valuable in correlating the Mesozoic strata of Britain and the continent.

The further discovery that organisms of such a lowly type as the Graptolites followed the same law of slow development, specific culmination, and extinction as that long acknowledged to be characteristic of the life-periods of the higher groups of animals, has added great force to these views. It has allowed us to unravel with comparative ease the ascending sequence in one of the most complicated districts among the contorted strata of the Southern Uplands and has shaken the fashionable and mystifying doctrine of Colonies, as interpreted by British geologists, to its foundations. The host of proofs which the detailed study of these fossils has disclosed that the supposed extended range and confused intermingling of their species does not actually exist, but is due, primarily, to defective stratigraphy, has led myself and others to suspect that the species of the remaining groups of Lower Palæozoic fossils will ultimately be found to have a similar restricted range in geological time, and, as a consequence, an equivalent value as indices of the systematic place of their containing stratum, and that palæontological evidences are destined soon to regain their ancient place in the regard of the working geologist among the older sedimentary rocks. The new interest and illumination thus cast upon the study of the Lower Palæozoic rocks are, it is hoped, certain to lead to the working out of these ancient strata upon a new and more minute plan, with the result of the discovery of a host of correspondencies at present unsuspected between British and foreign Lower Palæozoic sediments, and the gradual development of a detailed scheme of classification of widely extended application.

Now, not only are these Lower Palæozoic rocks of Carrick of all-absorbing interest to the palæontologist and geologist from their highly fossiliferous nature and their enigmatical stratigraphy, but they afford all the elements necessary for a crucial test of these special opinions. If the asserted heterogeneous intermixture of fossil assemblages of all types, elsewhere characteristic of distinct horizons, were actually found to obtain amongst them, palæontology might well abandon her claim to be the unfailing handmaid of stratigraphy among the more ancient formations. If, on the

other hand, the cautious study of these deposits led to the demonstration of the contrary opinion, *i. e.* that their distinct fossil assemblages were restricted, as in other lands, to different stratigraphical zones, British geologists would feel justified in attempting the correlation of their own Lower Palæozoic subformations with their nearest representatives all over the world.

In the following pages I shall give the results of a personal study of these Carrick rocks as they are exposed in the area which lies immediately to the east and south of the sea-port town of Girvan. If the testimony here brought forward be accepted, we are not only forced to the conclusion that these Lower Palæozoic strata attain a thickness and a geological importance hitherto unsuspected, while in the definiteness and gradation of their component subformations and in the abundance of their special fossils they bear favourable comparison with the classic deposits of Siluria itself, but we are also compelled to acknowledge that in the vertical sequence of these subformations, in the direction and amount of the development of life—even in the grouping of certain genera and species and in the restriction of defined assemblages to special zones—they correspond to a most remarkable degree with the homotaxeous or synchronous deposits hitherto studied in detail in Southern Britain, Europe, and America.

2. *General Characteristics of the Girvan Region.*

The fossiliferous Lower Palæozoic strata which will be noticed in the present memoir lie within and around the extensive and more or less elevated tableland which separates the lower portions of the river-valleys of the Girvan and Stinchar. Westward, this plateau is abruptly truncated by the waters of the Firth of Clyde. Its seaward margin is formed by a line of almost vertical cliffs, based upon a coast platform, which is alternately a raised beach and a submerged fringe of dangerous reefs and skerries. Eastward, its limits are defined with tolerable distinctness by the commencement of a superimposed terrace, composed essentially of more recent volcanic rocks, of the general age of the Old Red Sandstone. The south-western portion of the plateau itself forms the *subdistrict* of Ballantrae, which is occupied by igneous and altered rocks of undetermined age, and which will be therefore only casually referred to in the present paper. The major portion, or main Girvan plateau, to which our attention will be chiefly directed, and which is based upon the fossiliferous deposits, has a length, from the coast near Girvan to the edge of the Volcanic Terrace of Garleffin, of about 12 miles, and a breadth, from the edge of the Uplands to the southern slopes of the Girvan valley, of about 8 miles.

In addition to this main exposure, the Lower Palæozoic rocks make their appearance at the surface within the Girvan region in two subordinate and supplementary areas, viz. those of Craighead and Straiton. The *Craighead*, or Mulloch-Hill area, is formed of the wooded ridges lying to the north of the Girvan valley. It is a

partially faulted inlier of about six miles in length, by one and a half in breadth, bounded on all sides by Old Red and Carboniferous strata. The *Straiton* area is a faulted strip of Silurian rocks five and a half miles in length, by half a mile in breadth, lying several miles to the east of the main district, and forming the northern edge of the Old Red Sandstone terrace of Garleffin.

The southern boundary of the principal Lower Palæozoic area, or main Girvan plateau, is formed by the deep and narrow valley of the river Stinchar. Throughout the whole of its course in this region, from Barr to Ballantrae, the greatest width attained by this depression is about half a mile. To the south of this valley, the hills of the Southern Uplands are seen sweeping upwards in rounded grass-clad forms into the barren moorland area of Beneraird and the Merrick. To the north, the valley-slopes are steep and frequently abrupt, a range of picturesque heights, some 1500 or 1600 feet in elevation, overhanging the valley from Barr to Pinwherry. The numerous windings of the stream below enclose patches of fertile alluvial flats, or haughlands, which have long been under cultivation. A few woodlands and thickets margin the river, and creep partly up the hill-sides, while farmsteads and cottages are more than ordinarily numerous; but the valley in its general aspect is of the same peaceful pastoral character as those of the Southern Uplands.

The valley of the river Girvan, on the other hand, which bounds this main plateau on the north, is altogether much wider, and is wholly different in its physiographical aspect from that of the Stinchar. Along its southern margin the grassy steeps of the Hadyard, Saugh, and Straiton Hills plunge suddenly downwards from a height of several hundreds of feet, in a long straight line 10 or 12 miles in length running from Girvan to Straiton. Northward the depression is bounded by the wooded slopes of the inlier of Craighead and Mulloch. Between these limits the level valley has a breadth of from four to six miles, and stretches eastward into the interior as far as the eye can reach. Innumerable woodlands and numerous parks and mansions diversify its surface; and the frequent villages, hamlets, and farmsteads testify to the industry and wealth of its inhabitants.

At the mouth of the river-valley itself lies the little sea-port town of Girvan, which gives its name to the entire district. Its inhabitants are largely of Irish extraction, and are employed in fishing and agriculture.

The few streams that drain the Girvan plateau conveniently divide it into several well-marked *subareas*, individualized by certain local peculiarities of scenery or rock-structure. The shallow upland valley of the water of Assel (Plate XXIV.) effectually isolates the mound-like area of *Benan* and Auchensoul. The rapid stream of Penwhapple has excavated a gorge, three miles in length and nearly a hundred feet in depth, across the very centre of the northern section of the plateau, sharply separating it into the two subdistricts of *Saugh Hill* and *Knock-gerran*. A fourth or coast-area is formed by the raised beach of *Shalloch* and Ardmillan, to the south of the

town of Girvan; a fifth by the narrow strip of Lower Palæozoic rocks forming the northward slope of the *Hadyard* and Garleffin Hills; and a sixth by the lenticular inlier of *Craighead* and Mulloch Hill near Dailly.

The whole of the important subarea of the *Benan* and Milljoan Hills, together with much of the adjoining subareas, is floored by sheets of boulder-conglomerates of enormous thickness and remarkable composition, amid which lie patches and lines of fossiliferous limestones scattered confusedly over the face of the country. The *Saugh-Hill* and *Knock-gerran* subareas are composed of repetitions of flagstones and grits of variable composition, occasionally interspersed with shell-bearing pebble-beds and seams of purple and green mudstone. The shelly sandstones and *Trinucleus*-shales, for which the Girvan district has long been famous, occur only in the Craighead and Mulloch-Hill area which lies to the north of the Girvan valley. The barren strata exhibited in the fringing subarea of Dailly and *Straiton* to the south of that valley remind us of the greywackes and flagstones of the Southern Uplands.

The *strike* of the Lower Palæozoic rocks of the Girvan district is uniformly from N.E. to S.W. The *dip* of the beds varies. In the northern parts of the main plateau they dip steeply to the south-east, while to the south they have as distinctly a north-westerly inclination. Hence the majority of geologists have hitherto regarded the rocks of this plateau as forming a regular synclinal trough, whose oldest strata lay along the outer edges of the plateau and the newest in its centre.

Two gigantic *faults* have long been recognized as affecting the stratified rocks of this district. These occur on the opposite slopes of the valley of the Girvan, running approximately parallel to the general course of that stream, and throwing down between them a broad band of Carboniferous strata, from two to four miles in width. The northern, or *Craighead* fault, has been proved for a distance of about 21 miles; while the southern, or *Bargany* fault, is in all probability of equal longitudinal extent. The general direction of these faults is from N.E. to S.W.; in other words, their courses coincide with the general strike of the Lower Palæozoic rocks of the region. They are, in reality, *strike-faults*, whose existence would long have remained unsuspected were it not for the fact that, with respect to the overlying Carboniferous strata, they are more or less *dip-faults*, abruptly truncating the gently inclined Carboniferous beds, and flinging them down along two comparatively straight lines among the perpendicular or highly convoluted Lower Palæozoic rocks below.

A third fault, running along the southern slope of the valley of the Stinchar and having the same general N.E. to S.W. trend as the foregoing, was detected by Prof. A. Geikie during his detailed mapping of the district. By the officers of the Geological Survey the fault was originally looked upon as forming the southern limit of the Girvan district proper. The barren and monotonous strata lying to the south of this fault were classed as being of Llandeilo age, while

the more varied and richly fossiliferous deposits lying to the northward were assigned to the Caradoc.

I shall show in the sequel that these great faults are accompanied by a host of others, some of which are of even greater geological importance, and that to the presence of these gigantic dislocations many of the most vital difficulties which beset the study of the stratigraphy of this region are primarily due.

3. *History of Previous Discovery and Opinion.*

The earliest notice of the fossiliferous Lower Palæozoic rocks of Carrick occurs in a memoir on "Some Fossiliferous Beds in the Lower Palæozoic Rocks of Wigtownshire," contributed to the Geological Society of London by Mr. J. Carrick Moore, in 1849, and published in the Quarterly Journal of the Society for the following year. The author, after describing the Graptolitic strata of the Galloway coast in some detail, gives a brief account of a fossiliferous limestone he had detected among the so-called Silurian rocks of Carrick. This limestone he had personally examined in five different localities in the valley of the Stinchar, and had procured from it many well-preserved fossils, principally Brachiopoda. These fossils he submitted to Mr. Salter, who at once assigned this Stinchar Limestone to the general epoch of Murchison's Lower Silurian, and paralleled it with that of the Wrae Hill in the Uplands of Peebleshire, which had been recently brought into notice by the discoveries of Professor Nicol. In Salter's description and figures of these Carrick fossils, published as an Appendix to Mr. Moore's paper, we find the earliest notice of the genus *Maclurea* in Britain, together with incidental references to the collateral results of Professor Sedgwick's simultaneous discoveries in the Carrick rocks north of the Stinchar valley.

At the meeting of the British Association held at Edinburgh in 1850, Professor Sedgwick gave a verbal description of his partial study of these Carrick rocks, which he had studied in the field a year or two previously, and from which a large suite of fossils had already been collected under his superintendence. From the brief abstracts of his remarks subsequently published in the Report of the Association * and in the 'New Edinburgh Philosophical Journal' †, we gather that Sedgwick recognized two successive groups of Lower Palæozoic strata in this region—a *South-Girvan Group* and a *North-Girvan Group*. His South-Girvan Group, which included the Stinchar Limestone and all the remaining strata of the plateau south of the Girvan valley, was assigned, with doubt, to the Llandeilo formation of Murchison. His North-Girvan Group, which embraced all the strata of the Craighead inlier to the north of the Girvan valley, was more confidently paralleled with the shelly limestones then supposed to lie between the Llandeilo Flags and the higher Silurian rocks of South Wales.

* Report British Association, 1850, pp. 103 &c.
† Edinburgh Philosophical Journal, vol. li. pp. 253, 254.

Fired by Sedgwick's animated descriptions of the strata of the Girvan region, Sir Roderick Murchison visited the district immediately afterwards, in company with his friend Professor Nicol, and made a most careful investigation of its Lower Palæozoic rocks. Like Sedgwick, he brought away with him a large collection of the most characteristic fossils. These were subsequently submitted to the examination of the veteran Silurian palæontologist, Mr. Salter; and, fortified by the corroborative evidence afforded by these forms, Murchison published his results in his general memoir on the "Silurian Rocks of the South of Scotland," read before the Society in 1850, and issued in their Quarterly Journal for 1851 *.

This memoir is characterized throughout by all Murchison's keen geological insight, comprehensive grasp of detail, and brilliancy of generalization; and it remains to this day not only classic in respect of its origin, but the clearest, most comprehensive, and, if we have respect to the date of its appearance, the most reliable paper that has yet been published upon the Lower Palæozoic rocks of this region.

According to Murchison the Silurian strata here displayed consist of three main groups—an upper group of schists and flagstones, a middle group of shelly sandstones and conglomerates, and a lower group of limestones and schists. The highest strata were supposed by him to lie in the trough of the apparent synclinal formed by the rocks of the great plateau between the valleys of the Girvan and Stinchar, and to have their northern representatives in the Trilobite (*Trinucleus*)-shales of Drummuck in the Craighead inlier. His middle division embraced the prolific shelly sandstones of Mulloch Hill, the *Pentamerus*-gritstones of Saugh Hill, and the barren boulder-conglomerates of Kennedy's Pass. His lower division was supposed to be formed by the limestones of Craighead and the Stinchar with their characteristic *Maclurea* and associated volcanic and trappean rocks.

His highest zone, or Orthoceratite-flagstone, had no definite geological date assigned it; but Murchison had no hesitation in paralleling the middle or shelly sandstone division with his typical Caradoc Sandstone of Siluria, which at that time included the *Pentamerus*-beds, or Llandovery rocks, as a subordinate member. The Stinchar limestones he placed in the Llandeilo, in the lowest or Arenig division of that formation as then received, which was supposed to be characterized by its many interbedded trappean rocks.

Murchison's conclusions, strengthened as they were by many clear sections worked out in the field, were in perfect harmony with the ideas then generally entertained with respect to the physical and palæontological succession among the typical Silurian areas of Wales and the west of England, and were at once accepted by the majority of geologists.

In 1854 Professors Sedgwick and M'Coy made their famous discovery that the May-Hill, or Upper Caradoc Sandstone, or *Pentamerus*-beds of Siluria, had no connexion, either physically or

* Quart. Journ. Geol. Soc. 1851, pp. 137 *et seq.*

palæontologically, as believed by Murchison, with the Bala formation*, but actually formed the base of Murchison's Upper Silurian system. This was soon followed by Murchison's erection of the *Pentamerus*-bearing strata into the transitional formation of the Llandovery, and the extension of this improved classification to the corresponding strata outside the typical areas.

In 1867 appeared the fourth edition of Murchison's Siluria†, in which the veteran geologist incorporated and systematized these and other advances in the classification of the Lower Palæozoic rocks necessitated by the results of the researches of the officers of the Survey under his direction and their amateur contemporaries. In this work these Girvan strata are noticed in some detail; and, assisted by Professor A. Geikie, Murchison attempted a more detailed correlation than that suggested in his earlier memoir. But, though not expressly advocated in words, the same general order of succession is retained unmodified, except that the higher beds are referred to the newly instituted formation of the Llandovery, and are described as indicating a passage into the base of the Upper Silurian.

Confirmed in his original views of the general order of succession in this region by the new data supplied to him by Professor Geikie, Murchison again confounded the two distinct faunas of the shelly sandstones of Mulloch Hill on the north of the Girvan valley and the *Pentamerus*-gritstones of Saugh Hill on the south, and placed the much older fauna of the Ardwell and Penwhapple flagstones above both. Nevertheless he recognized most distinctly the heterogeneous character of the fauna of his middle group, and accounted for it on the theory that here "as in England and Wales, particularly as we ascend the series, we meet with rocks in which the upper and lower types of fossils are mixed together"‡.

In the following year Professor A. Geikie § published a brief *résumé* of the conclusions already reached by geologists respecting the sequence in the Girvan area, pointing out with great clearness and effect the tantalizing nature of the evidences obtainable in the district.

In 1869 the detailed examination of the strata of the region by the officers of the Geological Survey having been completed, sheets 7 and 14 of the one-inch maps of the district were issued to the public, accompanied by brief explanatory memoirs.

In sheet 14 and its accompanying explanation we are presented with much that is new and of great value. The anticlinal disposition of the strata of the Mulloch-Hill inlier is shown with great distinctness; the superposition of the Mulloch-Hill sandstones to the *Trinucleus*-shales of Drummuck established beyond dispute; while a sufficiency of palæontological evidence is adduced to make it evident that the former appertain to some portion of the Llandovery forma-

* Phil. Mag. ser. 4, vol. viii. p. 301.
† Siluria, 4th edit. 1867, pp. 155–158.
‡ Siluria, 4th edit. p. 157.
§ Transactions Geological Society of Glasgow, vol. iii. p. 74.

tion*. At the same time the existence of the long strip of Silurian strata near Straiton is made known for the first time, and a well-founded suggestion thrown out that it is of Upper Silurian age.

The new material supplied by sheet 7 and its explanation, which bears upon the rocks of the great plateau to the south of the Girvan valley, is, on other hand, comparatively unimportant. The rocks south of the Stinchar valley are described as of Llandeilo age, while the strata of the plateau itself, including the Stinchar Limestones and metamorphic rocks, are assigned to the Caradoc, with the dubious exception of some indefinable patches of Lower Llandovery. The limestone of the region is said to occur in lenticular patches imbedded in conglomerates. Beyond a suggestion that the section seen upon the coast-line near Shalloch is a synclinal form†, and thus corroborative of Murchison's opinion that the Ardwell Graptolitic flagstones are the highest visible beds upon the plateau, no evidence is adduced of an ascending sequence; and the description of the complicated rock-structure of the district is deferred until the publication of the neighbouring sheet 8, which has not as yet (1881) made its appearance.

This deficiency, however, is supplied to a large extent by Professor Geikie's section of the rocks of the southern plateau inserted in the fourth edition of 'Siluria'‡. From this we gather that the synclinal recognizable upon the shore-line is prolonged into the interior of the country, and that, as Murchison originally asserted, the Penwhapple Graptolitic flagstones occupy its centre. To the northward these are underlain by the *Pentamerus*-gritstones and pebble-beds of Camregan and Saugh Hill. The area of Benan Hill and of the Stinchar is occupied by a massive conglomerate having no clear relations to the foregoing, and including two distinct bands of limestone. To the south of the Stinchar valley this limestone- and conglomerate-series is faulted against the barren greywackes of the Uplands, while to the north of the valley it is transgressively overlain by the boulder-beds of the higher ridges of Benan Hill, which are assigned to the epoch of the Middle Old Red Sandstone.

The remaining publications treating of the sequence of the Lower Palæozoic rocks of Girvan may be dismissed in a few words, as they contain no definite physical evidences in support of the views advocated in them. In 1874 Mr. D. J. Brown, in a general paper on the Silurian rocks of the South of Scotland, advanced the opinion that the Caradoc of Girvan would be found to overlie the Llandeilo unconformably, and that the Mulloch-Hill strata are the only beds that can with propriety be assigned to the Llandovery §.

In 1876 the country was hastily examined by myself and its strata noticed in brief in the opening chapter of the 'Catalogue of Western Scottish Fossils,' where the beds superior to the Limestone were arranged by me in two main groups, the Graptolitic flagstones

* Explanation Sheet 14, Geol. Survey of Scotland, pp. 8 and 10.
† Explanation Sheet 7, Geol. Survey of Scotland, pp. 1–11.
‡ Siluria, fourth edition, p. 156.
§ Transactions Edinb. Geol. Society, 1874, pp. 316 &c.

of Penwhapple and Ardwell and the *Trinucleus*-beds of Drummuck being there placed for the first time in their proper relative position, but erroneously assigned to the Llandovery*.

The same year Professor A. Geikie published his Geological Map of Scotland, extending his classification of the Lower Palæozoic rocks of the Uplands into the Girvan region, replacing the Benan boulder-beds in the Silurian, and restricting the Caradoc colour to the Benan zone and the northern inlier of Mulloch Hill and Craighead.

The host of *palæontological* works already published treating of the Lower Palæozoic fossils of this region make frequent references to the probable geological age of the more prolific fossil-bearing zones. The large collections originally made for Professor Sedgwick afforded many of the most striking types of Silurian organisms figured in Sedgwick and M'Coy's 'Palæozoic Rocks and Fossils.' Throughout that classical work are scattered frequent allusions to the probable parallelisms of Girvan beds and their prototypes in Wales and the west of England. In the Supplement to this work, issued under Salter's care, subsequent to the death of Professor Sedgwick, these references are most accurate and valuable.

The four successive instalments of Mr. Salter's unfinished Monograph of the British Trilobites contain several peculiar types of Crustacea from this area; and the author, founding solely upon the palæontological evidence before him, as interpreted by his intimate knowledge of the vertical distribution of Trilobites in the Lower Palæozoic rocks of Wales, invariably assigns the Stinchar Limestone to the Llandeilo, the Penwhapple Grits to the Caradoc, and the Mulloch-Hill Sandstone and the *Pentamerus*-beds of Saugh Hill to Murchison's transitional formation of the Llandovery.

The corresponding Monograph of the Silurian Brachiopoda, which forms the final division of Mr. Davidson's great work, is greatly enriched by forms derived from the Girvan region; and though the author is naturally less confident in his geological deductions than Mr. Salter, his correlations are generally identical with those of that palæontologist.

In 1867, Professor Wyville Thomson described and figured some forms of Graptolites from the Girvan area, and on palæontological grounds suggested a material modification of Murchison's views of the succession, expressing his own opinion that the whole of the Girvan rocks belong to Murchison's Lower Silurian, and that the Orthoceratite-flagstones of Penwhapple should be placed at the base instead of the summit of the series, and are probably followed in ascending sequence by the Mulloch-Hill Sandstones, Craighead Limestones, and *Pentamerus*- or Saugh-Hill Grits.

The officers of the Geological Survey of Scotland have made important collections from the rocks of the Girvan district. A list of their species is appended to the "Explanation of Sheet 3," published in 1873; and upon the ground of the palæontological evidences they afford, Professor Geikie rightly concludes that in the "south-

* Catalogue of Western Scottish Fossils, 1876, pp. 13 and 2. Compare also Lapworth, Trans. Geol. Soc. Glasgow, 1879, pp. 78–84.

west of Ayrshire there occur representatives of Upper Silurian, Llandovery, Caradoc, and Llandeilo rocks" (p. 5).

During the last twenty years the more prolific fossil-bearing strata of the Girvan region have been most successfully searched by Mrs. Gray, the wife of Mr. Robert Gray, F.R.S.E., of Edinburgh, herself a native of this beautiful district. Aided by the various members of her family, she has collected from these beds a magnificent series of organic remains of all types, numbering at present between 20,000 and 30,000 specimens. This collection, which has been most generously placed at my service by Mrs. Gray, is at present under process of description in the well-known 'Monograph of the Silurian Fossils of Girvan' of Nicholson and Etheridge, and will be noticed more fully in the second portion of the present memoir.

In the three instalments of this important Monograph of the Girvan fossils by Professor Nicholson and Mr. R. Etheridge, Jun., a view of the general sequence on the same lines as those sketched out by Salter is advocated, and an attempt made to fix with more definite precision the geological date of some of the more fossiliferous zones. Founding upon the vertical distribution of the Trilobites, Mr. Etheridge suggests a Lower Bala age for the Stinchar Limestone, and a Caradoc age for that of Craighead and the Trilobite-flagstones of Penwhapple, and unites the *Trinucleus*-shales of Drummuck, the shelly Sandstones of Mulloch Hill, and the *Pentamerus*-Grits in the Llandovery. Professor Nicholson, on the evidence of the Corals, parallels the Craighead Limestone and Penwhapple beds (Balclatchie) with the upper part of the Trenton of N.E. America, and classes the Mulloch-Hill Sandstones and *Pentamerus*-gritstones and their equivalents in the Upper Llandovery or May-Hill group.

The remaining palæontological works treating of the fossils of the district will here be passed over, as none of them deal seriously with the vexed question of the ascending succession *.

II. Physical Relations of the Lower Palæozoic Rocks of the Girvan Region.

(A) The Benan Conglomerate and its associated Strata.

In attempting the development of the true physical relationship of strata so crumpled and dislocated as those of the Girvan region, our first task is to select some definite stratigraphical zone, as general datum-line or horizon of reference, from which to commence our labour, and to which to refer, as often as occasion requires, the several results of our more detailed investigations. An horizon suitable for this purpose must, almost of necessity, be composed of strata of a lithological character sufficiently striking to be identifiable upon all occasions with ease and certainty. It should be of sufficient thickness to form, at least, a distinctly marked

* A list of 21 palæontological memoirs bearing upon the Girvan fossils will be found in the Bibliography appended to the chapter on Silurian Geology inserted in the 'Catalogue of Western Scottish Fossils,' 1876, pp. 25–28.

feature in the ascending sequence; and, to be completely satisfactory for our special purpose, it should be of wide horizontal extent, so that it may afford a large number of points of reference upon the ground itself, that there may be no possibility of doubt or ambiguity as respects its true relationship to the remaining members of the succession.

It is, in truth, most fortunate for the student of the stratigraphy of the Girvan rocks that all these desiderata are afforded him by what is actually the most remarkable formation in the Girvan region—the great Boulder-conglomerate of Benan Hill; its extraordinary petrological character, composed, as it is, of masses of rounded boulders heaped tumultuously together in a faintly stratified sandy matrix, renders it identifiable at a glance in the field; its great thickness, as displayed in Milljoan and Pinjerroch, where its almost horizontal beds are apparently piled one above the other to more than 1000 feet in height, makes it, geologically, one of the most important members of the Girvan succession; lastly, in its geographical extension it excels all its sister formations, stretching in one vast and almost continuous band more than a mile in width from end to end of the entire region.

Selecting, therefore, this great Boulder-conglomerate as our general horizon of reference, we commence the description of the Girvan succession by an account of the stratigraphy of those subareas where its true relationships are most effectively displayed.

(*a*) *Description of the Typical Sections of the Valley of the Stinchar.*

The subarea which most satisfactorily exhibits the development and interrelationships of the great Boulder-conglomerate and its associated strata within the Girvan region is the mound-like ridge lying to the north-west of the little village of Barr and its bounding valleys of the Assel and Stinchar. The general contour of this area rises in successive steps from the average level of these valleys in the west, to a height of nearly 1200 feet in the east, where it merges into the elevated Old Red Sandstone terrace of Garleffin. Its three rounded summits of Benan Hill, Pinjerroch, and the Mull of Milljoan rise in succession abruptly from the southern edge of the long straight valley of the Stinchar to the respective heights of 900, 1000, and 1100 feet, forming between them a broadly rounded ridge, which occupies a superficial area of at least 15 square miles.

The whole of this ridge, together with its outlying dependencies of Barr and Balclatchie, from the low-lying river-valleys that bound it to the summit of its highest point, is composed almost entirely of one continuous sheet of the coarse Boulder-conglomerate. It is here made up of rounded masses of stone of all dimensions, from blocks several feet in cubical extent to chips the size of a marble. These blocks are generally of igneous origin, consisting of granites, porphyries, serpentines, and various felsites; they are occasionally intermixed with pieces of white and red quartz, and with rarer

fragments of hardened rocks, sandstones, and greywackes. These are all intermingled confusedly together in a sandy or ashy paste, composed of the same materials as the included pebbles, and usually of a dull greenish colour, but occasionally purple and sometimes almost black. All the included blocks are well rounded and smoothed by aqueous action; angular chips are extremely rare, and the grains of the matrix itself, except when distinctly ashy and crystalline, bear evidence, in their rounded forms, of long-continued attrition by water.

The physical geologist who attempts the study of this area finds, scattered confusedly over the surface of the ridge, patches of limestones and calcareous shales, trenchantly individualized by many well-marked lithological peculiarities, but having the most enigmatical relations with respect to the surrounding conglomerates. In their topographical distribution these calcareous rocks at first sight appear most capricious. In one locality an interrupted line of exposures of these peculiar beds can be traced for some distance; but suddenly it dies out in the most unexpected manner; and in the direction in which we should naturally expect its prolongation we find, instead, the great conglomerate extending continuous and unbroken. Nor do the many sporadic sections of these calcareous beds seem to possess any definite characteristics in common that would allow of their being paralleled in detail and brought into any thing like intelligible interrelationships among themselves. In one spot we find a mass of flaggy limestone 50 feet in thickness, without a trace of other fossiliferous strata; in a second, a similar thickness of calcareous shales bears it company; in a third, shelly sandstones and grits are also present in force. But while no two consecutive exposures offer us a succession precisely similar among the beds distinct from the great conglomerate, they all agree in the one fact that both above and below them the great conglomerate itself is seen in force with all its characteristic features, its gentle dip, and persistent N.E. and S.W. strike.

Nor are these the only difficulties. In some spots the conglomerate is separated from the flaggy limestones by several feet of concretionary shales; while in other spots not a trace of these shales is visible, but in their place the strata afford proof of an apparent unconformability. Boulders and nodules of the limestone are found in the lowest beds of the immediately overlying conglomerate; and the latter seems to repose irregularly in the hollows of the eroded upper face of the limestone itself.

Recognizing these complexities, and impressed mainly by the two grand facts of the interrupted nature of the calcareous beds and the apparent erosion at their summit, the officers of the Geological Survey, after mapping this subdistrict, adopted the only conclusion that seemed open to them, and taught originally that the limestones were irregular and sporadic phenomena, that they were imbedded in the great conglomerate, and that the combined mass was transgressively overlain by a second conglomerate, which, to judge from its gentle inclination, was probably of Old Red Sandstone age. When

subsequently they detected proofs of a possible unconformability at the base of the Caradoc beds of the Uplands, this Benan unconformability seemed to be very naturally accounted for, and its theoretical age was altered to the epoch of the Lower Bala.

Now, to a geologist who studies the strata in a general way, the foregoing conclusions are inevitable; and upon this ground the officers of the Survey were amply justified in their deductions. But when these enigmatical calcareous zones are studied foot by foot, and each exposure is compared minutely with its neighbours, very different conclusions are arrived at, and the stratigraphist is soon delighted to discover incontrovertible proofs of an orderly sequence, explanatory of the visible phenomena in every locality, and exhibiting the most perfect harmony in all its parts.

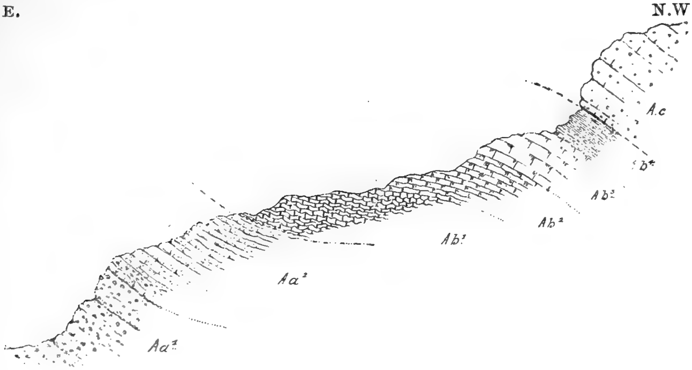
In the steep slopes of the hills of Benan and Auchensoul, which overhang the north bank of the valley of the Stinchar, a line of ancient lime-quarries is visible. These mark the place of a thick band of limestone, which ranges uninterruptedly from the farmstead of Minuntion to that of Auchensoul, a distance of about three miles. Throughout this extent, the limestone, beyond occasional and insignificant local slips, is unbroken by dislocations, and is fully exposed to the investigator in numerous artificial excavations, and in the beds and banks of the many little brooklets that drain the grassy summits of the Benan Hills. From end to end of this line, the limestone plunges into the hill-side at an angle of about forty-five degrees, below the wide-spreading and continuous mass of coarse Boulder-conglomerate already noticed, of which the higher points of Benan Hill and the neighbouring heights are composed.

1. *Benan Burn.*—About midway along its course the limestone and its associated beds are admirably exposed in the banks of the little stream of the Benan Burn, where the highly instructive section is displayed which is generalized in the accompanying figure (fig. 1).

The coarse green boulder-conglomerate of the region, which occupies the high ground of the ridge above, forms here a semicircle of steep slopes, partly enclosing a cirque-like area in the hill-side, where four little streams take origin that unite to form the Benan Burn. These steep grass-clad slopes show miniature cliffs of naked rock, composed of well-bedded masses of the great Benan conglomerate, showing all its characteristic features and dipping steadily into the hill-face at an angle of from forty to fifty degrees. The four rills unite in the centre of this cirque-like area; and a few yards above their point of confluence the coarse conglomerate suddenly ceases, and the naked banks of the most westerly rill show that we have here reached its basal beds, and that they repose upon a set of greenish concretionary shales and mudstones having the same trend and inclination as the conglomerate itself.

Didymograptus-shales.—These shales (Ab^4) have a collective thickness of about 30 feet. They are of a greenish-blue colour, hard, nodular, and more or less concretionary in structure, but of a fine texture and distinctly laminated. Under the hammer they break up into well-rounded nodules and irregularly concentric flakes. They

Fig. 1.—*Typical Section of the Strata of Benan Burn.*



Ac. Green Conglomerate of Benan Hill.

Ab. Stinchar Calcareous group:—
- Ab[4]. *Didymograptus*-shales.
- Ab[3]. Compact Limestones.
- Ab[2]. *Maclurea*-beds.
- Ab[1]. *Orthis-confinis* Flags.

Aa. Kirkland group:—
- Aa[2]. Red and grey Sandstones.
- Aa[1]. Purple Conglomerate.

are more or less calcareous throughout, effervescing distinctly on the application of acid.

They contain a few fossils, principally Graptolites, and those Linguliform Brachiopoda which are generally found in Graptolitiferous deposits. The Graptolites are procurable in fragments only, owing to the easily shattered nature of the shales and their concretionary structure, which render it a matter of impossibility to obtain a flat surface of large extent parallel to the line of bedding. But this defect is more than counterbalanced by the fact that the few fragments obtainable are all preserved in their full relief, allowing of their immediate specific identification.

The forms of Graptolites collected by myself from these green shales at this spot include:—

Didymograptus superstes, *Lapw.*	Glossograptus Hincksii, *Hopk.*
Dicellograptus sextans, *Hall.*	Cryptograptus tricornis, *Carr.*
Clathrograptus cuneiformis, *Lapw.*	Diplograptus rugosus, *Emm.*

The Brachiopoda are of few species, and embrace *Acrotreta Nicholsoni*, Dav., *Siphonotreta micula*, and a few forms of Lingulidæ.

Compact and nodular Limestones.—Below these *Didymograptus*-shales we come suddenly to a mass of pale limestones (Ab^{2+3}) admirably exposed in the beds of the little rills, in several artificial quarries, and in many occasional exposures seen below the cliffs of conglomerate in the surrounding slopes. The masses of pale limestone, pitted with innumerable superficial depressions, due to the

long-continued action of the weather, contrast trenchantly with the dark-green conglomerates of the cliffs above. The limestone is distinctly bedded in strata of flag-like character, from a few inches to two feet in thickness. The planes of bedding are, as a rule, perfectly regular; but occasionally their upper surface is more or less wrinkled or undulated, and the little hollows thus formed are filled with flakes of greenish shale, calcareous, and more or less concretionary in structure.

The thicker limestones, when split open, show, on rare occasions, an irregularly laminated interior, and the mass admits of being broken down into irregular flakes or sheets of an inch or so in thickness. But, as a general rule, the interior of the rock is quite homogeneous. It is of a dull grey tint, passing into black in its more compact parts, and shading off into a dull greyish green where of a more open character. In texture it is usually firm and compact, detached plates ringing under the hammer like clinkstone. When fractured it flies off in conchoidal fragments having much the appearance of hornstone or flint, with clouded surface and translucent edges.

In the more massive beds no trace of a fossil is discernible, and even in the less hardened parts there is generally little evidence of their presence beyond certain dim nebulous outlines, hardly suggestive of specific form. When greatly weathered, however, as in the many stone walls of the neighbouring fields, the fossiliferous nature of the nodular limestones is apparent at a glance; the faces of the bedding-planes are covered with elevated knots and patches, due to the former presence of corals and shells, the finer structure of the former and the half-obliterated outlines of the latter being easily recognizable by the eye. The spiral lines characteristic of the natural sections of the beautiful genus *Maclurea* are by no means rare under these circumstances; and the delicate structure of the peculiar coral-like *Tetradium* is even more abundant: while on rarer occasions we find patches covered with the roe-like *Saccammina*, occasional fragments of Trilobites, fractured Brachiopoda, and the like.

These limestones fall very naturally into two main subdivisions —a *higher* group of hard limestones (Ab^3), with rare dividing seams of calcareous shale and but few fossils; and a *lower* group of impure nodular and flaggy beds (Ab^2), which show, when fully weathered, abundant shaly partings and frequent examples of *Maclurea Logani*.

In these compact and nodular beds the calcareous matter is tolerably pure, and the limestones admit of being burnt for agricultural purposes; while in the underlying laminated beds next to be described the strata are largely impregnated with aluminous matter, and are of no special economical value.

It is difficult, if not impossible, to give an exact estimate of the united thickness of the compact and nodular limestones. To judge from the space they cover upon the ground, and from their vertical extent when plotted in section, it cannot be less than 60 or 70 feet; but in no locality elsewhere do they actually reach this thickness.

Orthis-confinis Flags.—In the locality under description the

impure *Maclurea*-limestones, already noticed, pass downwards into a similar thickness of calcareous flagstones, with way-boards and intercalated seams and flakes of greenish or brownish shales and mudstones (Ab^1). These are well exposed in the banks and bed of the little stream of Benan Burn; and their inferiority to the limestones is demonstrated by the fact that they can be followed by the eye coming out from below the latter in the steep slopes in regular order, and insensibly graduating from them in their petrographical characters.

In the upper limestones, as we have shown, the texture of the rock is usually firm and compact; and the calcareous matter being evenly distributed, the rock itself is solid and homogeneous throughout. In these underlying flagstones, on the other hand, the lime is not only much smaller in amount, but it is much more capriciously distributed, and the rock weathers more irregularly under the influence of the atmosphere. Instead of the hard, white, compact, and flinty-looking sheets of the upper beds, we now find the strata degenerating into a kind of impure flagstone or calcareous sandstone, containing nodules of lime, and assuming in places a honeycombed structure, whose hollows are filled exteriorly with soft rottenstone, which gives to the group a peculiarly dull olive-brown colour. In the steeper cliffs the soft rottenstone becomes wholly washed away, and the deeply honeycombed flaggy rock puts on a most peculiar and characteristic appearance.

In the compact limestones above fossils are, as we have shown, rare and excessively difficult of extraction; in these impure flagstones below they are, on the contrary, generally abundant and easily procured. They are, however, almost exclusively Brachiopoda, viz. *Orthis confinis*, Salter, *O. alternata*, Salter, *Strophomena grandis*, &c. Of these the species *Orthis confinis*, Salt., is emphatically the most abundant and characteristic, occurring everywhere throughout the region where these strata are exhibited, and occasionally abounding to the exclusion of all others.

Transitional Sandstone.—The bottom beds of these *Orthis-confinis* flagstones take on a dull purple colour, and, as we descend the succession, they gradually part with their calcareous nodules and degenerate into a group of purple grits and flagstones (Aa^2), which, in many of their essential features, remind us of some of the typical beds of the Old Red Sandstone.

In the present locality these purple sandstones are very fairly exposed, and have an estimated thickness of about forty feet. As a rule, they are simply coarse-grained, well-bedded grits, including many seams of coarse sandy shales. Above, they pass insensibly upwards into the *Orthis-confinis* flagstones last noticed; below, they contain seams of pebbles, first about the size of a marble, next of the size of the fist, till finally they graduate downwards into a massive purple conglomerate, which will be described in the sequel.

Such palæontological characters as these purple sandstones possess ally them to the overlying *Orthis-confinis* flagstones. An occasional seam is met with amongst them, affording a few casts of *Orthis con-*

finis and *Strophomena*; and the sandstone-group is best regarded as the zone of transition between the *Orthis confinis*-flagstones and the deep-seated purple conglomerate we shall next consider.

Purple Conglomerate.—Immediately below the basal beds of these *O.-confinis* sandstones a massive conglomerate suddenly sets in of most extraordinary petrological characters (Aa^1). In the present locality the contrast between this older conglomerate and the great boulder-conglomerate of the summit of Benan Hill is most striking. The Benan-Hill rock is of a dull greenish or greyish colour where freshly fractured, becoming more or less yellow upon its weathered surface. Its matrix is of a sandy, or ashy, and more or less open texture, and offers not the slightest indication of the presence of calcareous matter. In the much older conglomerate under description, which supports the *O.-confinis* sandstones, we see a rock of a wholly different character; its matrix is of a bright purple colour, and it is so highly calcareous that the mass is filled with patches of lime and veins of white calcareous spar. The included pebbles are of all sizes and all colours; green and grey porphyrites predominate, but granites, metamorphic rocks, limestones, and unaltered sandstones are all present and in no small abundance. The whole mass is intensely hardened and compacted together, so that it is next to impossible to detach a pebble from the general mass, the plane of fracture of the indurated rock traversing the pebbles and vitreous matrix alike. The brilliantly purple matrix of this conglomerate, veined with innumerable streaks of milk-white spar, forms a most exquisite contrast to the included masses of foreign material, green, grey, brown, and white, with which it is filled. The beautiful sight presented by a sheet of this rock, when seen at its best in the wetted cliffs of the many waterfalls that dash over it, lingers long in the memory of the investigator.

Of this purple conglomerate no great thickness is visible in the burn itself, but its beds may be followed by the eye in the rugged slopes of Craigbickarae a few yards to the west, coming out steadily from below the *Orthis-confinis* sandstones, and continued in unbroken mass downwards into the wooded slopes below, for a thickness of at least 150 feet.

This purple conglomerate forms the basal member of the Girvan succession as exposed in this locality. Its lowest beds are lost in the alluvial flats of the Stinchar below the base of Craigbickarae, and no further rock-exposure is visible for more than a mile to the southward.

Summary.—In this locality, therefore, we have evidence that the great green Benan conglomerate is conformably underlain by a series of older strata of very distinct petrological characters, namely:—

(1) A calcareous group, about 100 feet in thickness, composed of three members—(*a*) a set of nodular shales with Graptolites and Lingulidæ, (*b*) a set of comparatively pure and compact flaggy limestones, and (*c*) a set of impure calcareous flags.

(2) A purple conglomerate of great thickness and remarkable aspect, which graduates downwards from the foregoing group through a transitional zone of pebbly sandstones.

These results are epitomized in the following table:—

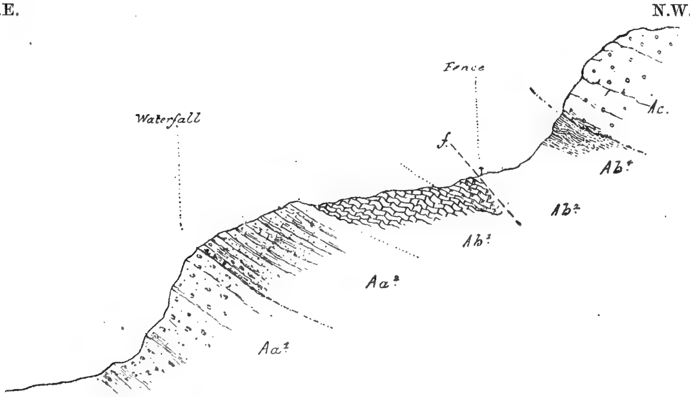
Ac. Benan-Hill (or Green) Conglomerate.
Stinchar Limestone group:—
Ab⁴. *Didymograptus*-shales.
Ab³. Compact Limestones.
Ab². *Maclurea*-beds.
Ab¹. *Orthis-confinis* Flags.
Kirkland group:—
Aa². Transitional Sandstones and Grits.
Aa¹. Purple (or Kirkland) Conglomerate.

I shall next proceed to show that the sequence thus indicated is that which obtains throughout the entire Benan area.

2. *Kirkland Burn.*—An excellent confirmatory exposure of the majority of the strata just described is to be seen in the neighbouring stream of Kirkland Burn, which has cut a deep channel down the slope of Benan Hill, about half a mile to the eastward of our former section. In this locality, however, the green Benan conglomerate is shown merely in a few scattered patches upon the hill-tops, the line of junction between the calcareous group and the Benan conglomerate is invisible, and merely a few fragments are seen of the *Didymograptus*-shales (Ab⁴) and of the upper parts of the Compact Limestone (Ab³) (see section below, fig. 2).

Fig. 2.—*Confirmatory Section in Kirkland Burn.*

S.E. N.W.



Ac. Green Conglomerate of Benan Hill.
Ab⁴. Green Graptolitic Shales.
Ab². Impure flaggy Limestones.
Ab¹. Calcareous and nodular Flagstones, with *Orthis confinis*, *Strophomena*, &c.
Aa². Purple Sandstones, Grits, and sandy Shales.
Aa¹. Purple Conglomerate filled with veins of calc-spar.

The highest beds visible appear to be the lowest zones of the *Maclurea*-beds (Ab²), which are well shown where a small fence crosses the stream. From this point downwards into the heart of the deep-seated Purple Conglomerate (Aa¹) the section is tolerably con-

tinuous, and the strata exposed admit of fairly exact admeasurement. We find evidences of some folds in the strata, and traces of slight faults, hitches, and wrinkles; but it is very doubtful if any of the beds are actually repeated, so that the following measured section may be relied upon as being approximately correct:—

	feet.
Ab^2. Nodular Limestones, thin-bedded, hard, unfossiliferous...	22
$Ab^{1\prime\prime}$. Calcareous Flagstones, full of nodules of limestone, more or less hardened, and only rarely fossiliferous	45
$Ab^{1\prime}$. Calcareous Flagstones, weathering to a russet-brown colour, and filled with seams and patches of rotten-stone	26

The section here fails us for some 13 feet of thickness, below which we find

$Aa^{2\prime\prime}$. Purple Sandstones, Grits, and Shales, with seams of pebbles, but no recognizable fossils	43
$Aa^{2\prime}$. Purple Sandstones and Grits .... passing down into	24
Aa'. Purple Conglomerate, full of rounded masses of igneous rocks, imbedded in a matrix of sandy and calcareous matter, veined with irregular seams of lime and calc-spar.	

The basal conglomerate is well exposed at a small waterfall overlooking the farmsteading of Kirkland. It will therefore be hereafter referred to under the alternative title of the Kirkland Conglomerate.

The ground to the south of the farm is covered with the alluvium of the Stinchar, and no older strata are visible.

3. *Auchensoul &c.*—In following the outcrop of the calcareous series along its line of strike towards the west, we find it become so greatly interfered with by a network of small faults that it is a matter of the utmost difficulty to map out the true place of the shattered fragments upon the ground. When, however, this task has been finally accomplished, it becomes evident that after leaving the Kirkland Burn, the limestone group begins to curve round rapidly towards the south-west, almost at right angles to its original course. It sweeps obliquely down the southern slopes of Anchensoul Hill, and crosses the valley of the Stinchar opposite the farmstead of Dupin, near which it is found dipping at a steep angle to the southward, and striking to the westward, in the wooded slopes of the hills on the southern side of the river, parallel to its original direction in Benan Hill. From its disposition upon the ground it may therefore be inferred that it is actually sweeping round the outer curve of a steep anticlinal arch, the main axis of which coincides with the line of the river Stinchar.

In the grassy slopes of Auchensoul Hill four main groups of exposures are recognizable. On the lateral terrace above the ruined church of Kirkdominæ, the Compact Limestone (Ab^3) is well displayed in some deserted quarries. In the most northerly of these, the highest zones of that division, immediately below, the *Didymo-*

graptus-beds (Ab^4) are laid open, and the dividing seams of calcareous shale contain an abundance of fairly preserved fossils.

The commonest forms are *Leptæna sericea*, *Orthis calligramma*, *O. biforata*, *Turrilepas*, sp., *Cythere aldensis*, *Asaphus*, *Encrinurus*.

These beds dip to the eastward at a small angle, and below them, in their natural position, we find the red sandstones (Aa^2) in an old cart-track on the hill-face above the ruins of Kirkdominæ.

In Kirkdominæ Burn the *Maclurea*-beds (Ab^{2+3}) are discernible, preserving generally their original line of strike, but greatly shattered and folded. Below we find a large development of the Purple Conglomerate (Aa^1) which is exhibited in the stream-course.

A well-marked N.E. and S.W. fault throws down a patch of the calcareous beds in their proper position below the Benan Conglomerate in the higher reaches of the little burn, on both sides of which the Compact Limestone (Ab^3) has formerly been excavated. To the west also the line of junction of the Benan Conglomerate (Ac) and the Calcareous Series (Ab) is visible for some distance upon the grassy hill-side. The green calcareous and concretionary *Didymograptus*-shales (Ab^4) are shown in their normal transitional position in several natural exposures.

In Auchensoul Burn, which lies about a quarter of a mile to the eastward of Kirkdominæ Burn, all that the many faults of this spot have left visible are certain lime-beds, full of pebbles of igneous rocks, imbedded in a matrix so highly calcareous that it almost deserves the title of a limestone. These possibly belong to the Purple Conglomerate of Kirkland (Aa). They are seen in the stream-course close to the farmsteading of Auchensoul.

4. *Dularg &c.*—Crossing the alluvial flats of the Stinchar, which are here only about 150 yards in width, we again come upon the calcareous series, dipping off the anticlinal arch to the south-east. They are exposed in the bed and banks of the river and in the wooded slopes around the farmsteading of Dularg.

In the bed of the river itself the greatly contorted *Orthis-confinis* flagstones (Ab^1), and patches of the *Maclurea*-beds (Ab^2), together with portions of the underlying Purple Sandstone and Conglomerate (Aa), are well displayed. In spite of their shattered character, the flagstones are, as usual, tolerably fossiliferous, and yield, among others, *Orthis confinis*, Salt., *Maclurea Logani*, Salt., *Strophomena grandis*, and fragments of *Orthocerata* and Corals.

The gentle eastward inclination of these strata is rapidly exchanged for a steeper one to the S.W., and their curving strike for a direct trend to the S.W., parallel with the normal range of all the strata of the region. The effect of this is that the limestone (Ab^3) next makes its appearance in two quarries close to the farm of Dularg, dipping steadily at a steep angle to the S.E., parallel in strike, but diametrically opposite in dip, to its position on the opposite side of the Stinchar valley in the slopes of Auchensoul. The limestones in these quarries at Dularg are of a purple colour and are greatly hardened, veined, and altered. These appearances are possibly due to the presence of

the enormous strike-faults which are known to affect the strata here, and which finally cut out the limestone band altogether a few yards west of the farmsteading.

5. *Craigbickarae Hill.*—Returning to the opposite side of the Stinchar, we resume our description of the unbroken line of the Benan and Auchensoul Limestone band at the point where we originally commenced. A few yards to the west of our typical section of the Benan Burn we find the calcareous series fairly exposed in the cliffs and upper terraces of the projecting mound of Craigbickarae. From the steep southern cliff of Craigbickarae itself the purple conglomerate looks out in great force over the valley. In the grass-grown terrace above the cliffs the *O.-confinis* flags (Ab^1) and their more arenaceous associates are buried beneath turf and surface-soil; but the overlying purer limestones (Ab^{2+3}) are shown in several small exposures, and, owing to the form of the ground, cover a large space upon the hill-side. The beds are much broken by faults and slips; but nevertheless the entire group may be easily followed upon the ground from point to point, everywhere emerging in its natural order and position from below the great mass of Benan conglomerate (Ac) which forms all the more elevated portions of the hills above. The line of contact between the limestone and conglomerate is, however, nowhere visible, the *Didymograptus*-shales (Ab^4) being either faulted out or overgrown with grass and vegetation.

In the small burn of Auchlewan the Compact Limestone is fully laid open, and in the steep hill-face to the right of it the *Orthis-confinis* Flagstones &c. are displayed and are abundantly fossiliferous, yielding chiefly *Orthis confinis*, Salt., *Strophomena*, *Maclurea*, *Tetradium*, sp.

The whole of the calcareous rocks dip steadily into the hill-face to the southward, at an angle of about 45 degrees, and are distinctly underlain by masses of the Purple Conglomerate and Sandstone (Aa), which are exposed for some distance in the channel of the little burn below.

6. *Auchlewan.*—In an exposure upon the line of junction of the Benan Conglomerate and the Calcareous Series, which is apparent a few yards to the west of the Auchlewan Burn, some remarkable phenomena are observable. In an old quarry above the outer fence of the enclosed and formerly cultivated area the line of contact of the limestone and conglomerate is plainly visible. The flaggy and compact limestones dip into the hill at their normal inclination, and are irregularly surmounted by a solid mass of conglomerate dipping in the same direction, but at a slightly inferior angle. The line of contact is most irregular. The limestone has all the appearance of having been greatly eroded previous to the deposition of the conglomerate. The regular beds of the limestones strike abruptly at the lower portions of the pudding-stone, and patches of the former are found adhering irregularly to the weathered basal beds of the latter. The conglomerate itself is almost destitute of any thing like bedding; but some of the natural planes of deposition are shown by the linear arrangement of bands of small pebbles. In its

lowest beds a few fragments of limestone are visible, of the general size of marbles. The appearances seen are difficult to explain upon the hypothesis of a fault, owing to the presence of the patches of limestone in the conglomerate; but if they are actually due to an unconformability we have to suppose that within the insignificant distance of about 200 yards the entire thickness of the *Didymograptus*-shales must have been eroded previous to the deposition of the basal beds of the Benan Conglomerate, and in addition some slight thickness of the Compact Limestone itself. It will be seen from the map that an important fault traverses the strata at this locality, and to its effects, combined with certain peculiarities of the basal beds of the conglomerate, which will be described in the sequel, the visible phenomena are most unquestionably due.

From this point the calcareous series is prolonged in a straight line to the south-west, descending the slopes diagonally towards the farmstead of Minuntion and the valley of the Stinchar. The nodular and Compact Limestones (Ab^{2+3}) are exposed in two fine artificial sections immediately to the west of the ruin of Auchlewan, dipping steadily into the hill-face below the masses of Benan Conglomerate, which crop out continuously in the higher parts of the overhanging slopes above. The usual fossils of the limestones may be collected with difficulty in the quarries and from the weathered masses of limestone in the neighbouring stone-dykes. Unfortunately the actual line of junction of the Calcareous and Conglomerate series is obscured, and it is impossible to collect any available evidence with respect to the apparent unconformability or fault-line of Auchlewan to the east.

In the steep ridges some distance north of the farm of Minuntion the limestone is seen in a shattered condition, suggestive of faulting along the junction-line. Immediately in the neighbourhood of the farmstead the Purple Sandstones (Aa^2) are visible in their natural position with respect to the limestone, preserving their steady dip of 45° into the hill-slope.

From the hill-quarry last mentioned the limestone may be followed in occasional exposures in a slanting direction down the slopes into the cliffs overhanging the stream of the Stinchar. Here we meet with a magnificent section in a large quarry, which until very recently was worked for the extraction of lime for the use of the farmers of the district.

7. *Minuntion.*—In this quarry the highest zones of the Compact Limestone group (Ab^3) are not exposed. The only strata quarried are the lower division of the *Maclurea*-beds and the underlying *O.-confinis* flags (Ab^1). The latter are well shown in the floor and sides of the quarry; they weather to their usual russet-brown colour, and are pitted with the usual hollows filled with rottenstone. The *Maclurea*-beds contain the usual characteristic fossils in abundance; the *Orthis-confinis* beds swarm with well-preserved Brachiopoda, &c.

The commonest forms include *Orthis confinis*, *O. biforata*, *Bellerophon*, *Strophomena expansa*, *Triplesia Grayi*, *Illænus latus*, &c.

This quarry may be regarded as the typical exposure of the *O.-con-*

finis beds. In no other locality known to myself are they so clearly exhibited, or their fossils so easily procured or so well preserved.

This quarry lies at the south-western extremity of the continuous band of limestone we have followed from Auchensoul and Benan Hill along the north slope of the Stinchar valley. The band here comes to an abrupt conclusion. It is bent back in a sharp curve, with an accompanying fault, and is thrown into an abrupt synclinal from below which rise the underlying strata of the deep-seated Purple Conglomerate.

This is well exposed in the floor of a small stream which here descends the slopes of the hill to the northward. It presents all the peculiar features of this remarkable formation as exhibited in the typical section of Kirkland and Benan. In the little wood we recognize it by its deeply purple matrix, marbled with veins of calcite, and filled with boulders of green porphyrites, grey granites, and fragments of altered rocks. Hard and firmly compacted, it is beautifully polished by the waters of the cascade, and forms a most striking floor to the darkened stream-course.

The synclinal and fault at this locality bring the typical line of the Stinchar calcareous series to an abrupt termination in the westerly direction, as do the anticlinal and accompanying faults of Dularg the same line in the opposite direction to the east. Before proceeding to the study of the scattered exposures of the strata of this group in the more complicated district to the northward, it may perhaps be advisable to re-summarize the points already established in the Girvan succession as here exhibited.

We find, that is to say, in the northern slopes of the Stinchar valley, that the great Benan conglomerate is underlain by a thick series of more or less calcareous strata, constituted of the following members in ascending order:—

	feet.
Kirkland Beds:—	
Aa^1. Purple Conglomerate of Kirkland .... (at least)	150
Aa^2. Transitional zone of Purplish Sandstones............(possibly)	50
Stinchar Limestone group:—	
Ab^1. Impure Calcareous Flagstones with *Orthis confinis*............	40
Ab^2. *Maclurea*-beds	30
Ab^3. Compact Limestones, less fossiliferous	30
Ab^4. *Didymograptus*-shales with Graptolites...........................	30
	330

That all these relations are retained essentially unmodified among the remaining exposures of this series in the Girvan district will next be demonstrated.

(*b*) *Description of the Confirmatory Exposures of the Calcareous Series in the Valley of the Assel Water.*

The whole of the great Benan-Hill ridge lying to the northward of the uninterrupted line of calcareous rock just described is, as we have already pointed out, composed of a continuous sheet of the dark green or Benan Conglomerate (Ac), which in our typical localities immediately overlies the *Didymograptus*-shales (Ab^4). From the

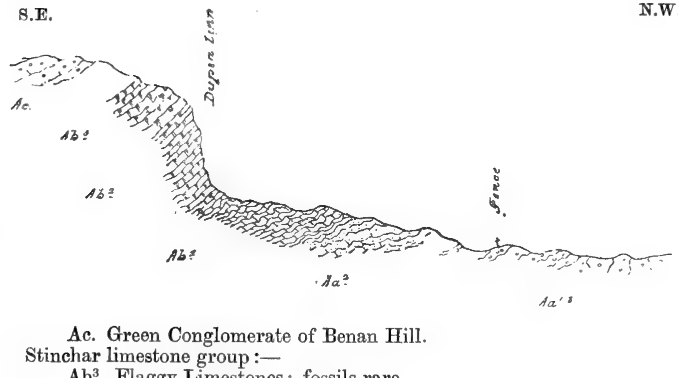
great quarry at Minuntion last noticed, eastward as far as the summit of the Mull of Milljoan, this conglomerate is exposed in every stream that has laid bare the strata below the grassy covering of the hill-tops. It varies much in colour, from black through dark green and yellow, and even purple; but we find few traces of an approach, either in colour, composition, or texture, to the beautifully marbled basal conglomerate of Kirkland and the Stinchar.

Throughout much of this extended area the Benan Conglomerate dips at very low angles and is even occasionally perfectly flat: indeed in the higher parts of the area, especially along the central ridge, this may be said to be the normal position of the rock.

As we approach the exposures of the calcareous series on the opposite sides of the ridge, the angle of inclination of the conglomerate increases irregularly to an average of about 45°. Along the typical Minuntion and Auchensoul line, as we have shown, this dip is universally to the *northward*. In the line of exposures between Dupin and Brockloch, which we have next to notice, the dip is in the opposite direction, or to the *southward*. This renders it highly probable, even at this early stage of our inquiry, that the Benan-Hill Conglomerate of this area will be found to be arranged in a synclinal form, and that the calcareous rocks which rise out from below it to the northward in the valley of the Assel will prove identical with those of our typical calcareous series of Minuntion and the Stinchar.

1. *Dupin.*—The first series of these exposures of calcareous beds is disposed in a broken line stretching from the Barr road near the foot of Pinjerrach Hill, down the southern slope of the valley of the Assel to Daldowie, and thence across the river-valley into the woods of Letterpin and Pinmore. The most satisfactory of the exposures

Fig. 3.—*Section of the Strata of Dupin Linn.*



Ac. Green Conglomerate of Benan Hill.
Stinchar limestone group:—
Ab³. Flaggy Limestones; fossils rare.
Ab². Impure Limestones with *Maclurea.*
Ab¹. Nodular calcareous beds with *Orthis confinis, Strophomena, Illænus,* &c.
Kirkland Beds:—
Aa². Purple and grey sandy beds, much shattered.
? Aa¹. Purple and green Conglomerate, broken and faulted.

along this extended line is that visible in the west glen of Dupin, a short distance above the edge of the alluvial trough of the Assel opposite the great lime-quarry of Tramitchell.

(1) *Dupin West Burn* (fig. 3).—About a quarter of a mile above the mouth of the little stream of the glen, coarse dark-green conglomerates are visible on its banks, dipping at varying angles to the southward, and apparently continued uninterruptedly above to the summit of the Benan ridge. A few yards below the most northerly of these exposures, thick beds of flaggy limestone are seen plunging into the hill-face at the same general angle of inclination as the green conglomerates. Where they cross the glen these limestones give origin to the small waterfall of Dupin Linn. They are fairly exhibited to a depth of about thirty feet, and repose upon a similar thickness of flaggy and more or less impurely calcareous beds, clearly the *Maclurea*-beds (Ab^2) of our typical sections of the Stinchar valley. These are underlain in their turn by nodular calcareous flags (Ab^1), which yield examples of *Orthis confinis, Strophomena expansa, Illænus*, &c. Next follow the unfossiliferous Transitional Sandstones (Aa^2), which graduate downwards in their turn into purple and green Conglomerates (Aa^1), varied with calcareous seams. In other words, if we except the easily eroded *Didymograptus*-shales, which are obscured by gravel, we find that all the members of the Calcareous series which we have studied to the southward are visible at this locality in their natural order and with their relative thickness.

Fig. 4.—*Section of the Strata of Dupin Mid Burn.*

Ac. Benan Conglomerate in its typical form.
Ac*. Conglomerate with limestone nodules.
Ab^4. Green calcareous shales with *Graptolites* and *Lingulæ*.
Ab. Limestones much distorted and faulted.
A ?. Green and grey flaggy Sandstones.

(2) *Dupin Mid Burn* (fig. 4).—The limestone of Dupin Linn may be followed across the grass-grown slopes to the north-eastward into the succeeding stream-course in that direction, where a second exposure of the band is laid open. Short as is the interval, the strata are much shattered and disjointed by small faults, and in the stream-bed itself only fragments of the band are visible. The highest strata seen are the coarse boulder-beds of the great Benan Conglomerates (Ac) of the usual character. The lowest bed of the Conglomerate (Ac*) is here filled with rounded nodules of limestone. To judge from the appearances observed, it is evident that these enclosures have not been derived from a local erosion of the inferior limestone, but that there has been a distinct continuation of the

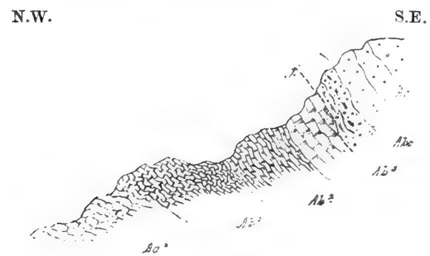
limestone-yielding conditions for a time into the era of production of the conglomerate itself. These nodular beds succeed a patch of calcareous shales (Ab^4) representative of the *Didymograptus*-beds, which contain a few characteristic fossils, principally Lingulidæ. This zone is irregularly underlain by the compact and nodular limestones, which are exposed in a small side quarry, and are, especially in their lower portions, greatly contorted and shattered. The section is terminated below by a series of sandy grits, probably those of the lower zones of the *O.-confinis*-beds. They afforded me no fossils, but they present the hollows and seams of rottenstone characteristic of the zone.

In the succeeding runnels which cross the prolongation of the limestone band to the eastward, the calcareous and conglomeratic groups are shown in a more or less shattered condition. The Benan Conglomerate (Ac) occupies the higher parts of the stream-courses. It is underlain in the natural order by patches of the limestone beds, which in their turn are supported by fragments of the underlying sandy gritstones. The rapidity with which the higher zones of the limestones part with their calcareous matter as we pass to the eastward is most remarkable, the whole of the upper beds showing a tendency to degenerate into a group of nodular shales.

2. *Craigwells or Brockloch Quarries.*—After traversing a short interval devoid of rock-exposures, we again meet with the calcareous band in a group of old limestone-quarries lying to the east of the farmhouse of Brockloch.

In the quarry situated at the disused limekiln of Craigwells we have the following section (fig. 5).

Fig. 5.—*Brockloch Quarry.*



Ac. Benan Conglomerate.	Ab^2. Impure flaggy Limestones.
Abc. Conglomerate with nodules of lime.	Ab^1. Nodular Limestones.
Ab^3. Compact Limestone, 20 feet.	Aa^2. Calcareous Flagstone.

To judge from this section, it would appear, at first sight, that the Compact Limestones (Ab^3) are surmounted immediately by the basal beds of the Benan Conglomerate (Ac), while the *Didymograptus*-beds (Ab^4) are absent from the section, having apparently been eroded, and that the overlying conglomerate rests unconformably upon an undulated face of the Compact Limestone, fragments of which occur

in abundance in the conglomerate itself. But the line of contact is clearly a fault, while the patches of lime in the conglomerate lie in regular seams, and have the appearance of being merely nodular concretions, as if the conditions favourable to the deposition of calcareous matter, which marked the epoch of the formation of the limestone series, were continued into the earlier stages of the period in which the Benan Conglomerate was laid down.

That this is the correct interpretation is placed beyond question by a careful comparison of the phenomena presented by the succeeding quarries to the north-west of this locality. In some of these the *Didymograptus*-shales (Ab^4) are lost through faulting; in others they are well displayed, and are found to possess all their usual characters, lithological and palæontological. Sections of the two most important of these exposures are given on the opposite page.

In the first of these (fig. 6) the *Didymograptus*-shales (Ab^4) are formed of a group of greenish shales and impure nodular limestones, and lie, precisely as in the Stinchar valley, between the *Compact Limestones* and the Benan Conglomerates. The basal beds of the latter are filled with limestone nodules, arranged generally along the lines of stratification, and weather to a light yellow or orange-colour.

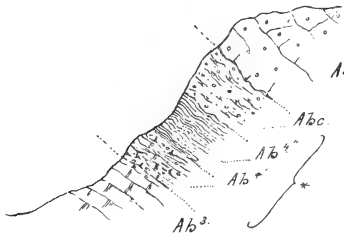
In the second (fig. 7) the *Didymograptus*-zone is most effectively displayed, and is seen to be composed, as usual, of bands of grey and green shales, which graduate from the Compact Limestones below, through a series of nodular beds, into the Benan Conglomerate above, the basal zones of the latter being filled with seams and patches of calcareous nodules, and weathering of the usual buff or orange tint.

The *Didymograptus*-shales themselves yield the characteristic fossils *Didymograptus superstes, Climacograptus nanus*, *Acrotreta Nicholsoni*, &c.

Summary.—Our study of this portion of the Dupin-Brockloch band has taught us that along this line there is no line of irregular erosion at the base of the Benan Conglomerate. In Dupin, midway along its course, the *Didymograptus*-beds (Ab^4) are present in force, and with their typical aspect as exhibited in the Minuntion and Stinchar area. As we pass eastward along the deserted quarries of Brockloch and Craigwells, their place is distinctly occupied by a thin group of nodular limestones and Graptolitic shales, surmounted by conglomerates full of seams and balls of calcareous matter. These overlying beds, though they appear to be derived partially from the reconstructed débris of the calcareous series, are rather interpretable as evidence that the era between the period of deposition of the Stinchar calcareous series and that of the Benan Conglomerate was a period of oscillation, and that the lime-producing conditions which prevailed during the time of deposition of the Stinchar calcareous series were prolonged into the earlier stages of the epoch in which the tumultuous Benan Conglomerate was formed.

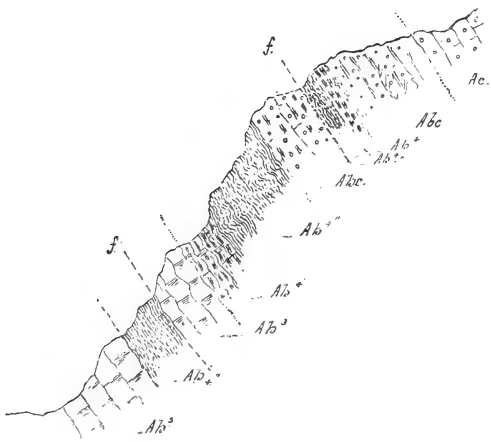
To the north of that portion of the Dupin-Craigwells limestone

Fig. 6.—*Section of Quarry North-east of Craigwells.*



Ac. Benan Conglomerate (here weathering of an orange tint).
*. *Didymograptus*-zone or passage-beds between Stinchar Limestone group and Benan Conglomerate.
Abc. Yellow Conglomerate with limestone-nodules.
$Ab^{4''}$. Green calcareous Shales with *Lingulæ*.
$Ab^{4'}$. Nodular and impure flaggy Limestones.
Ab^3. Compact Limestones.

Fig. 7.—*Section of Quarry between Brockloch and Little Lane Toll.*



Ac. Benan Conglomerate, weathering of an orange tint, 4 feet.
Passage-beds or *Didymograptus*-beds :—
Abc. Yellow Conglomerate with nodules of limestone, 6 feet.
$Ab^{4''}$. Green calcareous Shales, 8 feet, with *Lingula, Acrotreta Nicholsoni, Diplograptus*, &c.
$Ab^{4'}$. Nodular and impure flaggy Limestones, 4 feet.
Ab^3. Compact Limestones, without visible fossils.
ff. Faults.

band we have last described the green and yellow beds of the Benan Conglomerate are visible, extending, so far as can be ascertained, in an unbroken mass from the limestone band to the sluggish stream of the Assel Water. Hence it may be regarded as almost certain that this southerly dipping limestone band is here brought to the surface by a sharp anticlinal, ranging from N.E. to S.W., a small fault running along its summit and depressing the strata to the north. On that side, except at Dupin Linn, nothing is visible of older date than the Benan Conglomerate (Ac). On the south-east margin, however, as we have seen, various thicknesses of the Stinchar calcareous series are recognizable, the deepest strata visible being the Purple Conglomerate and Sandstones (Aa) of Dupin Linn, which we identified at the point where we commenced our study of the band.

This anticlinal and its accompanying fault are probably prolonged continuously to the south-westward in the same general straight line; but as the Benan Conglomerate is seen in some small exposures in this direction immediately west of Dupin Linn, while the limestone is found in place along a parallel line some 500 yards to the southward, it is possible that the fault varies much in throw, and is accompanied by parallel dislocations of equal extent.

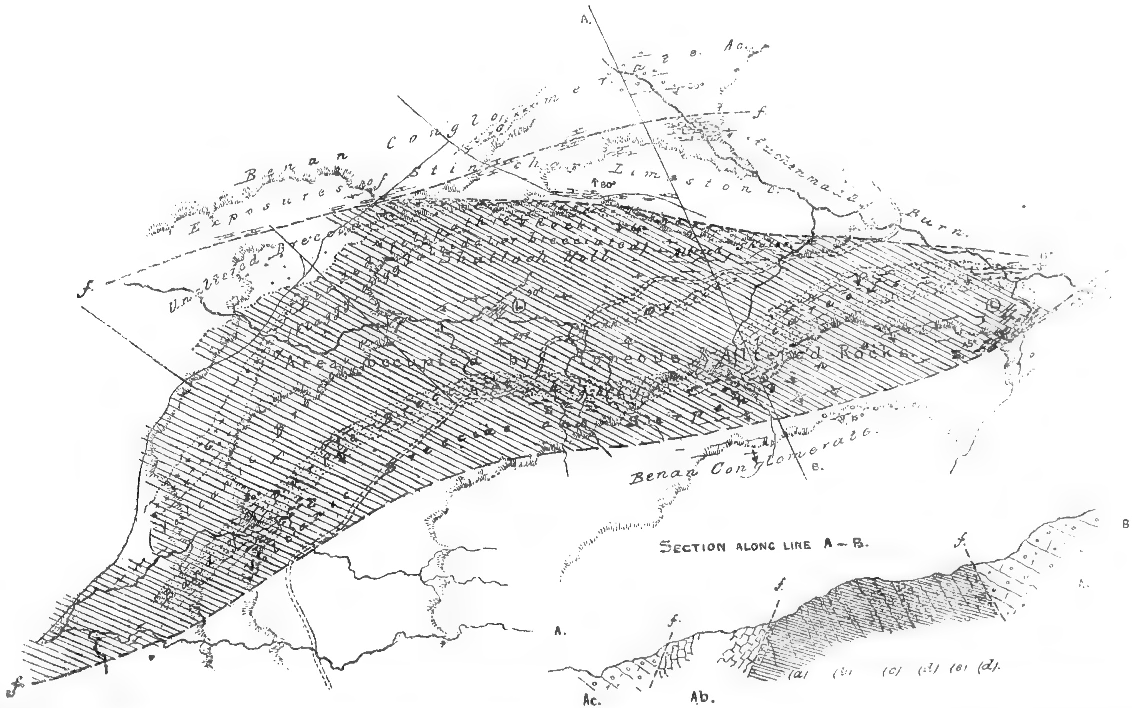
3. *Shalloch-Hill Exposures.*—Less than a mile to the west, however, the calcareous series again makes its appearance in the exact prolongation of the Craigwells fault, as we are presented with a fairly continuous section half a mile in length and of very great interest.

The limestone is seen in several old quarries excavated in the north slope of Shalloch Hill. In the easternmost of these quarries the strata are much dislocated, and their junction with the interesting rocks to the southward is obscured. In the second quarry the limestones lie between calcareous flags weathering with a honeycombed surface, probably the *O.-confinis* flags (Ab^2), and soft shales and nodular grits representative of the transitional zone of Craigwells and Brockloch. Westwards the same flaggy limestones are seen projecting from the surface of ploughed fields, and eastwards in the bed of the small burn of Auchenmaddy.

These calcareous beds are succeeded to the north by the great Benan Conglomerate; while to the southward they are in contact with the remarkable mass of Shalloch Hill, which will be presently described. Difficult as it is to discern any stratigraphical evidence of value in the Shalloch exposures of these limestones, a study of their geographical distribution, as shown upon the map, renders it almost certain that they are brought to the surface by the Craigwells anticlinal and fault.

Immediately to the south of these quarries we meet with a most remarkable exhibition of the Stinchar calcareous beds and their underlying purple conglomerate, in the rugged area of Shalloch Hill itself (fig. 8), which forms one of the outer buttresses of the Benan ridge. Within this area, which is about a mile in length and

Fig. 8.—*Plan and Section of the Shalloch-Hill area.*



Ac. Benan Conglomerate. Ab. Stinchar Limestones: (L) patches of unaltered limestone surrounded by altered rocks. Ballantrae rocks:—(*a*) felspathic bedded rocks; (*b*) altered shales; (*c*) purple calcareous brecciated conglomerate; (*d*) serpentinous rock; (*e*) altered breccias (ashes). Intrusive rocks:—(G) Gabbro; (Σ) Serpentine. *ff.* Faults.

half a mile in breadth, occur patches of limestones, felspathic grits and breccias, and bedded igneous rocks, all intensely crumpled and crushed together, and pierced by dykes of diorite and serpentine. This area is limited by faults both on the north and south, outside of which lie the unaltered beds of the Benan Conglomerate.

On both margins of the area we find the beds of the calcareous series ; and the general disposition of the greatly wrinkled strata is that of an irregular anticlinal.

Shalloch Hill.—All the central part of this remarkable area is formed of grey and purple felsites, breccias of igneous rocks, altered shales, and a peculiar purple brecciated conglomerate. This last-named rock forms the longitudinal axis of the area, and is well displayed in open quarries and prominent bosses of naked rock. Except in its excessive induration and the presence of much serpentine and serpentinous matter, it irresistibly reminds us of the basal conglomerate (Aa^1) of Kirkland. The pebbles of igneous rocks enclosed are generally smaller than those of the Stinchar rock ; but the brilliantly purple matrix, highly calcareous and traversed by innumerable veins of spar, is identical.

The associated felsites, breccias, and gabbros are, however, most distinctly those of the much older *Ballantrae Series*, in which corresponding calcareous breccias (calcareous and serpentinous ash-beds) occur at several localities. At the same time the hardened and altered rocks of the present area are fringed to the N.W. (see plan, fig. 8) by unaltered breccias, similar to those of Millenderdale, which lie apparently between the conglomerate and the *Ballantrae Series*. I am therefore inclined to the opinion that the whole of the hardened and igneous rocks and dykes of this Shalloch-Hill area are of older date than the Kirkland Purple Conglomerate (Aa^1), and are here brought to the surface along a faulted anticlinal.

Nevertheless there are difficulties even upon this theory; for calcareous strata belonging to the *Orthis-confinis* Flagstones (Ab^1) are visibly entangled among the purple beds in the very centre of the area and afford several of the characteristic fossils in a fair state of preservation. They are even better exhibited in the neighbourhood of the Dupin fault near the edge of Auchenmaddy Burn on its north-east margin, where *Orthis confinis* and *Strophomena alternata* are not uncommon.

4. *Little Letterpin.*—The Craigwells fault, which forms the northern boundary of this area, is prolonged from the Shalloch quarries across the valley of the Assel into the elevated ground to the west of the farm of Little Letterpin, where the limestone was formerly worked for agricultural purposes. In this locality we have a repetition in miniature of the phenomena of Shalloch Hill. The limestone seen in the old quarry consists merely of a few feet of very impurely calcareous rock, greatly shattered, dipping irregularly to the southward, and faulted abruptly against the main mass of Benan Conglomerate to the south. The higher points of Little Letterpin Hill consist of the purple grits and breccias of the altered series.

These are prolonged for nearly a mile to the south-west, and are much interfered with and hardened by protrusions of gabbro, which has been forced through the beds in a complicated plexus of dykes and veins.

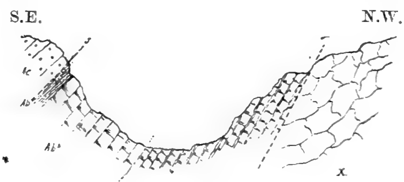
The Stinchar beds of this locality lie apparently between two converging faults, which appear to be the prolongations of those which bound the Shalloch-Hill area. These unite to the south-west into a single line, which may be most conveniently regarded as part of the Craigwells dislocation, which is continued in this direction into the metamorphic rocks of the valley of the Lendal.

(c) *Description of the Supplementary Exposures south of the Girvan Valley.*

1. *Aldons Quarry.*—Before entering upon the study of the scattered exposures of the Stinchar calcareous series to the north and west of the Benan-Hill ridge, it will be advisable to turn aside for a while, and examine the magnificent exhibition of these rocks in the quarries at Aldons and their extension in the south-west. The massive conglomerates of Benan Hill are continued uninterruptedly from the highest points of the Benan ridge across the lower valley of the Assel Water into the steep slopes of Aldons Hill west of Pinmore. About a mile south-west of Pinmore Bridge the great conglomerate is reduced almost to a point between two converging faults, which have thrown it down in a narrow synclinal among the Ballantrae metamorphic and igneous rocks. The limestone is seen coming out from below the Benan Conglomerate on both sides of this synclinal; and its relations to the rocks above and below are admirably shown in the large quarries which have long been opened at this locality.

In the north-west quarry and in the sides of the roadway leading thence towards the valley of the Stinchar we have an excellent exhibition of the rocks.

Fig. 9.—*Section of Large Quarry, Aldons.*



Ac. Benan Conglomerate.
$Ab^{4'}$. Shaly beds with *Ampyx, Leptæna*, &c.
Ab^{3}. Compact Limestones.
Ab^{2}. Impure flaggy Limestones with *Maclurea Logani, Cythere aldensis*, &c.
x. Igneous rocks of the *Ballantrae Series.*

This quarry (fig. 9) is opened along the line of fault between the *Ballantrae* rocks and the Girvan Series. The lowest bedded rocks

exposed are impure calcareous flagstones (Ab^2). These are greatly shattered and crushed by the fault, and weather down into small irregularly shaped fragments, which, upon the dissolution of their included calcareous matter, subside into a black mud. They are actually thin-bedded limestone-flags, with a wrinkled, pitted surface, the irregularities of which are filled up with soft dark mud of a flaky texture. They yield many examples of *Maclurea Logani* of large size, together with myriads of the minute crustacean *Cythere aldensis*, M'Coy. It is difficult to estimate the thickness of these *Maclurea*-flagstones, but it cannot be less than 30 or 40 feet.

They are succeeded by the Compact Limestone beds in thick strata, clearly identical with the Compact Limestones of Benan Burn. No reliable estimate can be formed of their original thickness at this locality, but it must have been somewhat less than that of the subjacent flagstones.

At the east end of the quarry a fault has brought down the more gently inclined Benan Conglomerate against these Compact Limestones; but as we trace the fault in its course along the face of the quarry to the west, some of the intermediate beds make their appearance below it. These consist of thin-bedded greenish-grey shales of some ten or twelve feet in thickness, clearly representative of our *Didymograptus*-beds of the Kirkdominæ band and the corresponding zone of Craigwells (Ab^4). They are here abundantly fossiliferous, being crowded with casts of fossils of the genera *Agnostus*, *Illænus*, *Remopleurides*, *Lingula*, *Acrotreta*, and *Leptæna*, together with *Cythere* and fragments of Encrinites. The remaining quarries of this locality are opened along the southern line of fault, where the calcareous series is seen in contact with the igneous rocks, but too greatly shattered to afford fossils.

It would be superfluous to point out how easily the succession in this locality is interpreted by the facts we have already obtained in the Benan-Hill area, and how complete is the identity of the various zones of strata as here exhibited with the corresponding rocks of the typical calcareous band of Auchensoul and Minuntion. The inferiority of the Stinchar calcareous series to the Benan Conglomerate and the natural arrangement of the members of that series having now been satisfactorily determined, we turn with the confidence born of certainty to the study of the remaining exposures of these beds in the Girvan district, treating of each exposure as briefly as is consistent with the object we have in view.

The great fault in the southern quarries at Aldons is well shown in the railway-cutting above Pinmore Bridge. Here a few feet of the Compact Limestones are seen in a shattered condition between the metamorphic or igneous rock and the overlying sheet of Benan Conglomerate, the whole dipping at a gentle angle to the north-west.

The same fault is seen in the Stinchar near Pinmore Bridge; but there is no trace of the limestone.

Several exposures of the calcareous series occur, however, in the prolongation of this line to the north-west. In the heights to the

north of Kilpatrick the limestone is seen in several localities, in thin courses and in several neglected quarries, greatly interfered with by protrusions of gabbro, and having no definitely regular relation to the surrounding sheet of the Benan Conglomerate (see map 2, Plate XXV.). Faulted patches of the same rock are visible along the extension of the Aldons dislocation to the north, as far as the summit of Daldowie Hill. Their geographical disposition may be gathered from a study of the accompanying map of the region.

2. *Tramitchell Quarries &c.*—By far the most important exposure of the Stinchar Limestone south of the Girvan valley, from an economic point of view, is undoubtedly that presented in the great lime-quarries at Tramitchell in the valley of the Assel. Here the limestone is quarried in a steep cliff which overhangs the roadway for a distance of at least 200 yards. It seems at first sight altogether much thicker and purer than in any other exposure in the entire Girvan region; and next to the quarry of Craighead, to be noticed in the sequel, this quarry certainly affords the chief supply of lime for the district. It is mined in large quantities, burnt in the kilns upon the spot, and led upon a tramway to the railway-station at Pinmore.

At a first glance it would appear that at least 100 feet of Compact Limestone are developed at this locality; but this apparently abnormal thickness is delusive, and the limestones are actually of no greater vertical extent than elsewhere. A long strike-fault bounds them to the north, throwing down against them the highest zones of the overlying Benan Conglomerate. The limestones, which include also the whole of the *Maclurea*-zone, are crumpled up against this fault in a broken anticlinal form, and dip with several small step-slips, visible in the quarry-face, steadily to the southwards, as if passing below the Benan Conglomerate of the flats of the Assel.

The sharp anticlinal in the neighbourhood of the fault is well seen at the eastern extremity of the exposure. Some of the more impure and nodular beds on the floor of the quarry take on an oolitic structure, a very rare phenomenon among the limestones of this region.

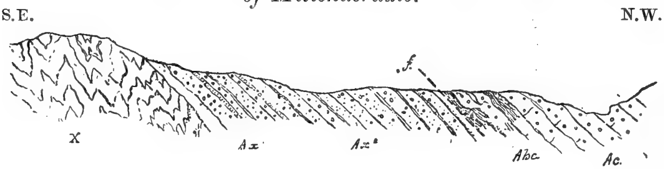
In the purer flaggy limestones at the summit of the anticlinal occur the peculiar fossils *Saccammina Carteri* and *Girvanella problematica*, which, together with fragments of Encrinites and *Tetradium*, are very abundant. The lower *Maclurea*-flagstones in the centre of the quarry yield *Maclurea Logani*, *Ecculiomphalus Bucklandi*, *Orthis calligramma*, *Strophomena corrugatella*, and their usual associates.

The wide-spreading and continuous mass of Benan Conglomerate of the upland area of Benan and Auchensoul, to which we have hitherto restricted our description, seems originally to have expanded to the westward into a broad sheet many square miles in superficial extent, around and above the metamorphic and igneous rocks of Lendal and Ballantrae. The powerful dislocations which have affected the Girvan district have, however, shattered this broad sheet into four distinct fragments. Two of these, forming the high

grounds of Millenderdale and Laggan, are still continuous with our typical mass of Benan Hill. The remaining two, which occur upon the ridges of Trowier and the Byne Hill, are now separated from the Benan ridge and each other by two gigantic strike-faults, which have thrown down between them strata of much later geological age. Not only is the present geographical arrangement of the rocks of these areas almost demonstrative of their original continuity, but their detailed study shows, as might have been expected, that they agree precisely in all their petrological characters with their prototypes of Benan Hill, and are similarly underlain by a group of calcareous beds answering exactly to our limestone series of Auchensoul and the Stinchar.

3. *Millenderdale area.*—The most southerly of these supplementary areas is formed by a narrow prolongation of the Benan Conglomerate, about three miles in length by half a mile in width, which stretches from the typical area at Kinclaer viaduct upon the water of Assel, into the heart of the Ballantrae rocks upon the water of Lendal. It is distinctly interposed between these igneous rocks and the sheet of Graptolitic flagstone which everywhere succeeds to the Benan Conglomerate in the Girvan district. The peculiar relations of this strip of conglomerate to the neighbouring Ballantrae rocks need not detain us here. It will be sufficient for our present purpose to state that a careful mapping of the area makes it clear that it forms, generally speaking, a faulted anticlinal. Near its western extremity the Stinchar Limestone emerges from below it in a group of old quarries and natural exposures near the farmsteading of Millenderdale. A few specimens of *Saccammina Carteri*, and *Tetradium Peachii* are procurable from these limestones. In the deserted quarry west of the steading, in spite of the shattered state of the beds, we recognize with certainty the Nodular Flags (Ab^2) at its northern extremity, followed by the Compact Limestones (Ab^3), for the extraction of which the excavation was made, and finally a few feet of the superior greenish shales of the *Didymograptus*-beds (Ab^4) are seen in the stream-course to the south-west.

Fig. 10.—*Basal Zones of the Girvan Succession, south-west of Millenderdale.*



Ac. Benan Conglomerate.
Abc. Graptolitic shales with *Diplograptus rugosus, Crypt. tricornis,* &c.
Ax. Base of Girvan Conglomerate.
Ax^2. Well-bedded ashy conglomerates and sandstones.
Ax^1. Coarse breccias of fragments of igneous and altered rocks, with interstratified purple sandstones and red and green grits and shales.
x. Igneous and altered rocks of *Ballantrae Series.*
f. Fault.

In the bed and banks of the small stream which drains the grassy heights to the south-west of this locality an interesting section of what appear to be the basal breccias and sandstones of the Girvan succession is laid bare. The lithological characters and physical relationships of these beds will be apparent upon a study of the foregoing section (fig. 10), but their detailed description is reserved for a future occasion.

4. *Dinvin and Laggan Hill.*—Northward of the anticlinal and fault of Letterpin and Brockloch a long tongue of the Benan-Hill Conglomerate runs westward from the quarries at Tramitchell along the north side of the Assel, and, expanding rapidly as it is followed in this direction, finally forms a broad rounded mass more than two square miles in area, in the rugged heights of Laggan and Dinvin. The beds of this sheet of conglomerate are thrown into innumerable undulations, which are well seen in a host of natural exposures; but none of these are of sufficient magnitude to bring the underlying calcareous series to the surface. Westward, however, the conglomerate area is bounded by the complicated group of dislocations which surround the Old Red Sandstone outlier of Glendrissock; and in their neighbourhood we find exposed the basal beds of the conglomerate, together with a few feet of the infrajacent calcareous series.

From the farmhouse of Pinnacher for some distance towards the narrow gorge of Laggan Gill the deepest beds of the conglomerate dip at a gentle angle to the south-eastward below all the overlying masses of Dinvin. Rising out from beneath these, in their natural order, we find the Stinchar Limestone in two disconnected spots. The first of these is an old quarry, a hundred yards north-west of the steading of Pinnacher, where hard compact limestones form a rude anticlinal, the eastern side of which is overlain by calcareous flaggy shales dipping towards the great conglomerate of Dinvin. The only fossils I have collected from these beds are undeterminable Brachiopoda; but the officers of the Geological Survey have been more fortunate, as they enumerate in their list of organic remains from Pinnacher the characteristic and peculiar Stinchar forms *Maclurea Logani*, Salt., and *Lyopora favosa*, M'Coy.

In the second exposure, which occurs in a deep bay of the conglomerate, about half a mile to the north-eastward, a fairly satisfactory section is seen, showing the beds of transition between the calcareous series and the Benan Conglomerate. At this locality the basal beds of the Benan rock dip at a medium angle to the eastward below the continuous mass of the neighbouring slopes; they weather with the orange-yellow tint characteristic of the corresponding beds along the northern margin of the Benan area. the nodular calcareous seams of the Brockloch zone at the base of the Benan rock here unite into a distinct band of limestone, more than a foot in thickness, which is both overlain and underlain by coarse conglomerates, thus affording us a complete demonstration of the conformability of the Stinchar and Benan strata.

A short distance to the south a branch of the Glendrissoch fault steps forward the conglomerate of Dinvin into the mound of Laggan

Hill, and an altered patch of the *Ballantrae* calcareous series comes out from below it at the head of the Laggan Gill.

5. *Trowier Hill.*—The summit and south-west scarp of Trowier Hill, which lies between the two forks of Piedmont Burn, about half a mile north of the last-mentioned locality, are formed of an irregular dome of the Benan Conglomerate. The south-western limits of the conglomerate area, as expressed upon the map (Pl. XXIV.), are purely inferential, as the natural surface of Piedmont Hill itself is obscured by moss and vegetation. In the centre of the dome of Trowier itself, however, we have distinct evidence of the presence of a calcareous series in place, in the numerous excavations formerly made for the purpose of extracting lime, in the existence of an old lime-kiln, and in the abundance of scattered fragments of altered calcareous rock. Such fragments as are capable of interpretation give no evidence that the higher Compact Limestones have been obtained at this spot; but seem to belong rather to the impure and more or less ashy and serpentinized band of the *Ballantrae Series.*

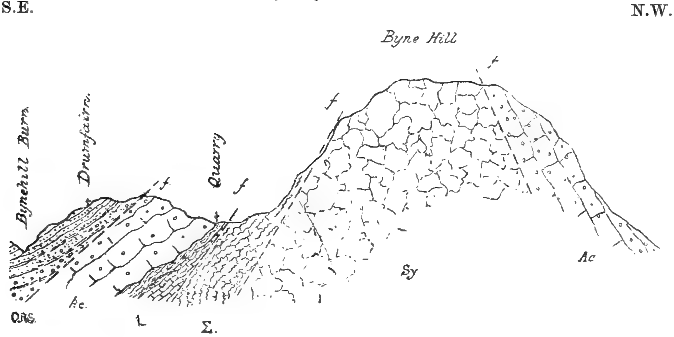
6. *Dow Hill.*—A marked and most symmetrical anticlinal of the same Benan rock forms the conspicuous knoll of Dow Hill, a short distance lower down the water of Piedmont. No great thickness of the conglomerate is here exposed, but its infraposition to the surrounding strata of the neighbouring slopes (the Graptolitic flagstones and shales to be presently described) is most perfectly exhibited.

7. *Byne Hill and Kennedy's Pass.*—The most conspicuous and best-known of the many exposures of the Benan Conglomerate in the Girvan district is undoubtedly that of the Byne Hill and Kennedy's Pass. It forms the northern and steeply descending flank of the igneous ridges of Grey Hill and Pinbain, in an unbroken sheet about four miles in length. It is beautifully displayed in the rugged mound of the Byne Hill (fig. 11), which forms the most conspicuous object in the picturesque view of this ridge and the old sea-terrace at its foot from the town itself. The arrangement of the rocks in this hill will be understood from the following generalized section. Its core is formed of a mass of syenitic granite, which is followed to the south-eastward by a strip of the peculiar serpentinous rock so abundant in the Ballantrae region. These igneous rocks are flanked on both sides by the Benan Conglomerate, which is composed of the usual tumultuous masses of boulders of igneous rocks imbedded in a greenish and more or less ashy paste, and occasionally divided by seams of coarse sandstone and bedded grit. On the north side of the hill the beds in contact with the syenite differ in no essential respect from those constituting the main mass of the conglomerate; but on the south-eastward slope we find certain calcareous beds rising out from below.

A limestone is seen in an old quarry on the line of fault between the serpentine and the conglomeratic area of Drumfairn, at the head of a small tributary of the Byne Hill Burn. About 10 feet of Compact Limestone is visible, dipping 60° or 70° S.E., shattered and more or less serpentinized where it is in contact with the fault-line

below, and passing upward regularly into flaggy and more shaly beds above. These are at once surmounted by the Benan Conglomerate.

Fig. 11.—*Section across the Ballantrae and Girvan Rocks of Byne Hill.*



O. R. S. Conglomerates and sandstones of Old Red Sandstone age.
Ac. Benan Conglomerate in its ordinary characters.
L. Crushed and altered limestones of doubtful age.
Σ. Serpentine.
Sy. Syenitic granite of Byne Hill.
ff. Faults.

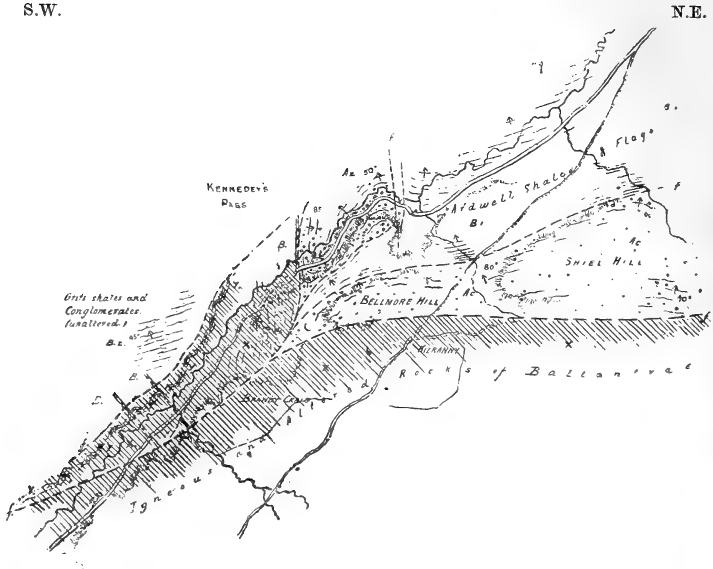
The same beds may be traced a short distance in both directions, and are possibly cut out to the south-west by a transverse fault passing through the farmhouse of Drumfairn.

From Byne Hill the Benan Conglomerate is traceable in an unbroken strip to the sea-shore at Kennedy's Pass (fig. 12). It varies much in its transverse diameter throughout this extent; but as it nowhere exhibits any of the naturally underlying limestones, so far as may be inferred from the phenomena exhibited in the few exposures upon the hill-slopes, it seems probable that throughout the whole of this extent its south-western edge is faulted down against the igneous series of Ballantrae.

The dividing basal fault is well seen where the conglomerate comes upon the sea-shore, and is traceable for some distance in a south-westerly direction, running almost parallel with the shore-line. Where it finally disappears beneath the water it is joined at an acute angle by a second strike-fault coming down the coast-line from Shalloch and Ardwell. In the angle formed by these two converging faults there is a grand exhibition of Conglomerate at the well-known locality of Kennedy's Pass, where it was first studied by Murchison and Nicol, and where it has been frequently examined by recent students of the rocks of this region. In the roadway and cliffs at this point the numerous transverse dislocations which have affected it admit of easy recognition, and the conglomerate itself

Fig. 12.—*Plan of the Faulted Area of Kennedy's Pass.*

S.W. N.E.



Girvan rocks :-

B¹. Graptolitic shales and flagstones of Ardwell.
Bx. Green flagstones, shales, and conglomerates, non-fossiliferous.
Ac. Benan Conglomerate.
Ax. Basal Conglomerate of Kennedy's Pass.

Ballantrae rocks :—

x. Ashes and breccias, igneous rocks, amygdaloidal traps, &c.
y. Band of altered limestone and calcareous breccia.
ff. Faults. B B. Basaltic dykes.

is laid open to view in one of its most typical forms. The matrix of the basal division is finer and altogether less calcareous than in the interior districts, while the pebbles are generally smaller and by no means so numerous ; but in all its essential features the mass cut through by the roadway reminds us of the ashy Basal Conglomerate of Millenderdale and the Stinchar, while that which occurs upon the ridge above is identical with our typical conglomerate of Benan Hill and Auchensoul.

(*d*) *Description of the Fossiliferous Exposures north of the Girvan Valley.*

1. *Craighead Quarries.*—Next to our typical exposure of the calcareous series in Benan Burn and Auchensoul in the valley of the Stinchar, by far the most important exhibition of the Stinchar Limestone is that afforded us in the great lime-quarries of Craighead on the north side of the valley of the Girvan. These quarries are

excavated in the south-west flank of the prominent ridge of Craighead and Quarrel Hill, in the immediate neighbourhood of the Glasgow and South-western Railway, about a mile to the east of the railway-station of Killochan. The gigantic fault which here forms the northern limit of the Carboniferous basin of the Girvan valley runs at this point parallel to the railway, immediately in front of the quarries themselves. Several loop-faults or inosculating branches of this grand dislocation are given off along its course to the north-westward; and caught up between these, and abruptly collocated with strata of comparatively recent geological age, we find long lenticular masses of the conglomeratic and calcareous division of the Girvan succession we have been studying to the southward. The most important of these loop-faults surrounds the mound-like hill of Craighead, enclosing a lenticular mass of rock of peculiar character, a mile in length and half a mile in breadth. The main mass of the lenticle, which forms the hill itself, is clearly identical with the enigmatical rocks of Ballantrae, and, like them, is formed of a congeries of rocks partly aqueous and partly igneous, the latter, again, being partly bedded and contemporaneous, partly intrusive and subsequent. At the eastern end of the lenticle, however, these rocks are surrounded by a mass of limestone and calcareous strata, of a semicircular form, limited at both ends by the bounding faults, and dipping generally from off the igneous and hardened rocks.

It is in this semicircular mass of limestone that the Craighead quarries have been excavated. They are two in number—an older quarry lying on the southern curve of the semicircle, and a newer quarry running along its eastern edge. The former has been long exhausted of its superficial and more easily excavated limestones. The latter is in constant working to supply the demands of the agriculturists of the neighbourhood, the lime being burnt in kilns upon the spot, and delivered by special tramway at the railway-station of Killochan.

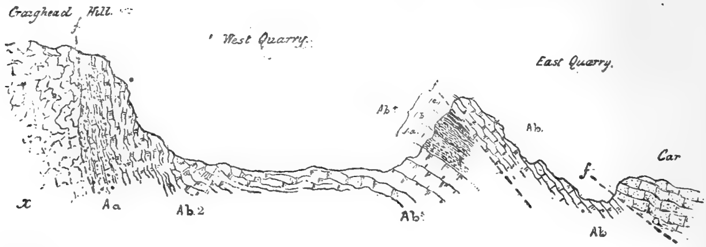
The general arrangement of the calcareous rocks of this locality will be apparent on a study of the following section (fig. 13).

The two sets of calcareous strata excavated in the quarries form, with respect to each other, a rude synclinal, which has been broken along its central line. Their physical arrangement is best displayed in a section drawn through the south quarry parallel to the great fault.

At the south-western end of the quarry calcareous and ashy conglomerates, representative of the basal conglomerates of Kirkland (Aa), are seen in vertical and even partially inverted position in contact with the igneous rocks of Craighead Hill. They pass below a thick group of nodular beds (Ab^1 and Ab), which, arranged in a basin-like form, run in perpendicular cliffs round the western and northern faces of the quarry. These are actually concretionary limestones, rendered very impure by the presence of much soft green and grey mud. They contain an occasional *Maclurea*, and are crowded with an abundance of corals, the beautiful tracery of which may be made out by the lens in all the white seams and bands that traverse the face of every new-made fracture of the beds.

Fig. 13.—*Section of Craighead Quarries.*

S.W. N.E.



Stinchar Limestone Group.
- Ab4. *Didymograptus*-zone:—
  - (*c*) Shivery shales with *Encrinurus, Ampyx, Leptæna*, &c.
  - (*b*) Blue calcareous and slightly carbonaceous shales with *Climacograptus bicornis, Diplogr. rugosus*, &c.
  - (*a*) Nodular and highly calcareous shales crowded with fossils.
- Ab3. Compact Limestones, fossils rare.
- Ab2. Impure flaggy and nodular limestones, greatly shattered and folded, with rare *Maclurea Logani* and abundant corals.
- Ab. Sandy and flaggy limestones with *Orthis, Leptæna*, &c.

Kirkland Conglomerate.
- Aa. Basal brecciated and calcareous conglomerate and grit.
- *x*. Igneous and altered rocks of Craighead Hill.
- Car. Lower Carboniferous sandstones of the Girvan valley.
- *ff*. Faults.

The floor of the quarry itself and the little cliff supporting the roadway to the south is composed of the purer and more compact limestones which give the quarry its economic value. They are here greatly hardened and have a pale greyish-white tint when freshly broken. They contain a larger proportion of carbonate of lime than elsewhere, and seem to have been quarried in thick and heavy masses. A few of the same fossils are procurable from them as those found in the muddier beds below, but they are much more difficult of extraction.

The terminal beds of these compact limestones are seen at the foot of a boss of unexcavated rock which at present divides the two quarries from each other. This boss owes its existence to the circumstance that the strata of which it is formed contain too little lime to be available for burning; and they have been allowed to remain, while the surrounding limestones have been quarried away. The strata seen in this boss are, however, of great value to the stratigraphist, as they enable him to complete the entire section of the calcareous series visible at this locality.

In the western cliff of this mound the Compact Limestones are seen to be overlain by about 10 feet of grey and black Graptolitic shales, identical in mineralogical character with the *Didymograptus*-shales (Ab4) of the Auchensoul band. They contain a few Graptolites and shells. Of the former, Mrs. Gray has here collected *Cryptograptus tricornis*, Carr., sp., and *Diplograptus foliaceus*, Murch.

In the grass-grown flank of the boss on its south-west aspect these Graptolitic shales pass upwards into an equal thickness of hard

greyish-yellow shales crowded with casts of fossils of the genera *Encrinurus*, *Ampyx*, *Trinucleus*, *Leptæna*, *Strophomena*, *Orthis*, and *Cythere*.

Above these we find traces of the usual nodule-bearing conglomerate.

These fossiliferous shales are truncated at an acute angle by the strike-fault which runs along the axis of the synclinal between the two limestone-quarries. On the opposite side of the fault we find the more muddy and concretionary *Maclurea*- and coral-beds. The tramway and grassy slopes below hide the main mass of these from sight; but when we search the roadway beneath we find evidence that they have in turn been underlain by green and purple sandstones, more or less pebbly, resembling the *Orthis-confinis* Sandstones of the Stinchar (Ab^1) in appearance and composition, and in the presence of calcareous nodules, as well as in stratigraphical position. They contain the usual forms of *Orthis*, *Leptæna*, and *Strophomena*, and terminate the visible section.

It is needless to insist upon the fact that we have in this locality a section similar in all its details to that typical of the Stinchar calcareous series of the district to the south of the Girvan valley, the natural members of the succession corresponding precisely in both districts in their position in the vertical series and in their petrological and palæontological characters, and differing merely in local thickness.

In one grand respect, however, the calcareous rocks of Craighead differ in a most extraordinary degree from their counterparts of the Stinchar plateau. In the latter district, these strata, though rarely affected by igneous protrusions, are, as a general rule, strangely barren of organic remains throughout their entire vertical extent. In the present locality, though the beds have been greatly shattered and hardened by faulting and crushing, fossils occur in profusion. The indefatigable researches of Mrs. Gray at this locality have been rewarded by the discovery of at least 100 different species of fossils of all the chief Lower Palæozoic groups, affording the palæontologist of the present day a more complete view of the fauna of the period than he would be able to construct from all the zoological data hitherto collected in Britain bearing upon the rocks of Craighead age.

These fossils will be treated of in detail in the second part of the present memoir, and it will only be necessary here to make a few notes upon the remaining exposures of the calcareous beds seen in this locality.

The strata in the new or eastern quarry are folded and faulted repetitions of those already described, crushed up against the igneous strata of Craighead Hill on the west, and passing out of sight below the roadway and clay-covered ground to the east.

2. *Calcareous beds of Thunderton and Glenrochie.*—The same calcareous series is seen at several points along the Craighead fault, both to the south-east and north-east of the quarries themselves; but few of the sections seen are worthy of an extended notice. Near the farmhouse of Glenrochrie, a line of deserted quarries affords

good exposures of the shattered beds of the calcareous group. The purple, veined, and brecciated basement conglomerate of Kirkland and Millenderdale is well exhibited, distinctly lying between the Ballantrae rocks and the calcareous series. The latter displays both the impure sandy zone of the *Orthis-confinis* beds and the overlying concretionary flagstones, yielding occasional examples of *Maclurea Logani*.

(B) The Graptolitic Flagstone Series of Ardmillan and Penwhapple.

Having completed our description of the chief exposures of the great Benan Conglomerate and the calcareous strata which naturally underlie it, our next task is the determination of the nature and vertical distribution of the several groups of strata which immediately succeed it in the ascending order.

The difficulties which confront us in our quest are almost insignificant when contrasted with those we have had to overcome in our study of the calcareous zones below. The outer or superior edge of the great Benan Conglomerate is usually defined with tolerable clearness upon the ground. The highest zones of its massive boulder-beds dip almost everywhere below an overlying series of Graptolitic flagstones and shales of a totally distinct petrological character.

These Graptolitic flagstones occupy the whole of the Lower Palæozoic area south of the Girvan, with the exception of that filled by the Benan-Conglomerate group and a narrow zone lying to the northward of the parallel of Saugh Hill. They are magnificently exposed in the deep gorge of Penwhapple and along the coast-line between Shalloch and Ardwell, while numberless confirmatory sections occur elsewhere.

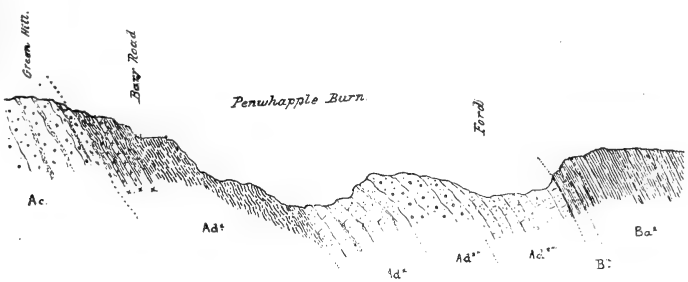
Everywhere along the boundary-line between the Benan Conglomerate and the Graptolitic-flagstone series, where the sequence is unbroken, we find an intermediate zone of highly fossiliferous strata, which, both petrologically and palæontologically, partakes of the characters of the underlying conglomeratic group and the overlying flagstone series, and which therefore it will be more convenient to treat of in this place before entering upon the description of the typical sections of the Graptolitic series.

(*a*) *Description of the Transitional Zone of Balclatchie.*

At the extreme north-western boundary of the continuous conglomeratic sheet of Benan and Milljoan it is crossed by the infant stream of Penwhapple, which has excavated a narrow gorge in its highest beds near the Assel road, between the grassy slopes of Knockgerran and Balclatchie, exposing a most instructive section of their junction with the basal beds of the dark Graptolitiferous flagstones and shales of the overlying series.

1. *Balclatchie Bridge* (fig. 14).—At the highway-bridge of Balclatchie, which there spans the gorge, and for about a hundred yards below it, the Benan Conglomerate is recognizable in all its charac-

Fig. 14.—*Typical Section near Balclatchie Bridge.*



Ba. Ardwell Graptolitic Shales and Flags.
- a¹. Dark carbonaceous and iron-stained shales, with *Graptolites.*
- (*n*) Basal zone of calcareous and carbonaceous shales, with *Climacograptus Scharenbergi*, *Lasiograptus Harknessi*, and *Cryptograptus tricornis.*

Ad². Balclatchie Grits and Conglomerate.
- d²'''. Ashy gritstones and flaggy beds, fossiliferous.
- d²''. Calcareous boulder conglomerate, with *Lingula canadensis.*
- d²'. Green flaggy gritstones, calcareous, fossiliferous.

Ad¹. Balclatchie Shales.
- Grey and green calcareous and nodular mudstones, highly fossiliferous—with *Barrandia*, *Remopleurides laterispinifer*, *Ampyx Hornei*, *Asaphus gigas*, *Siphonotreta micula*, *Dicranograptus tardiusculus*, &c.

Ac. Benan Conglomerate.
- Coarse conglomerate and interbedded sandstones, with boulders of quartz and felsite.
- *, *, *. Basaltic dykes.

teristic features. Boulders of quartz, granite and felstone, often of large size, are confusedly huddled together in a greenish matrix composed of a sandy or more or less ashy material, which weathers on the surface to a dull orange tint. Its highest beds are well exposed in some small cliffs that overhang the roadway to the north of the bridge, where they exhibit distinct evidence of their bedded nature in the visible arrangement of the rounded balls of white quartz and grey porphyrite in regularly parallel lines, and in the distinct alternation of coarse conglomeratic bands with others of a sandier texture. These all dip steadily to the northward, at an angle of from 50 to 60 degrees, and distinctly follow each other in unbroken sequence.

The highest beds of the conglomerate proper can be studied foot by foot in these cliffs. Towards their termination they become somewhat looser in texture, and the matrix of the rock grows more sandy. At their summit, where they are pierced by three small basaltic dykes of a most interesting character, they pass up conformably into an overlying group (the *Balclatchie Beds*, Ad) of calcareous shales and mudstones and flaggy grits, highly fossiliferous. The unbroken continuity of the sequence at this locality is easily demonstrated. The pebble-beds characteristic of the Benan Conglomerate below, and the shaly beds characteristic of the Balclatchie zone above, distinctly alternate with each other in a curious group

of passage-beds, in which the characteristic Balclatchie fossils may be collected from the shale bands lying below the terminal pebble-beds that mark the final disappearance of the peculiar physical conditions which gave origin to the Benan conglomerate.

Balclatchie Shales, Ad^1.—The lowest division of this overlying fossiliferous group is composed of about 40 feet of concretionary mudstones of a dark bluish-green colour. and excessively jointed. They are somewhat calcareous, usually effervescing upon the application of an acid, and weather down into shivery fragments, the joints of which are coated by the yellow oxide of iron. They are well exposed upon the roadside; but they are even better displayed in a small cliff on the opposite side of the stream-course, a few yards distant. In the cliff, however, and in the floor of the stream at its foot, they are but slightly weathered, and they compose a tough homogeneous mass, which flies into rough conchoidal fragments only after repeated blows of the hammer. These green mudstones (which resemble the greenish *Didymograptus*-mudstones at the base of the Benan Conglomerate in all their petrographical characters), contain a profusion of organic remains, generally fragmentary, but always in an excellent state of preservation. This spot has long been known to palæontologists for the abundance and beauty of its fossils; and the fauna of these green shales has been more completely worked out than that of any other single horizon (with the exception perhaps of the Craighead Limestone) in the Girvan region.

The more characteristic fossils obtainable here are:—

Dicranograptus tardiusculus, *Lapw.*
Dicellograptus moffatensis, *Carr.*
Glossograptus Hincksii, *Hopk.*
Asaphus gigas, *De Kay.*
Remopleurides Barrandii, *Ether.*
Theca simplex, *Salt.*
Lasiograptus Harknessi, *Nich.*
Climacograptus Scharenbergi, *Lapw.*
Lingula attenuata, *Sow.*
Acrotreta Nicholsoni, *Dav.*
Leptæna corrugatella, *Dav.*

Balclatchie Grits and Conglomerates, Ad^2.—The small group of fossiliferous shales is succeeded immediately by a thicker set of sandstones and conglomerates of a most distinctive lithological character.

The matrix of these overlying sandstones is of a dark green tint, passing into a blackish-blue colour upon the weathered faces. Their lowest strata are flagstones (d$^{2'}$), each a few inches in thickness, and partly formed of coarse irregular grains of felspar &c., as if derived from the washings of a greenish porphyry or volcanic ash.

Here and there the beds are finer; but nowhere are the component grains of sufficient fineness to reduce the rock to the nature of a shale. It is, throughout, a coarse roughly bedded sandstone, breaking up into flake-like plates an inch or so in thickness, having the irregularly wrinkled or undulated bedding-faces characteristic of laminated dykes and volcanic gritstones.

These flaggy sandstones, which yield an occasional badly preserved Brachiopod or coral, pass up into several feet of a coarse green conglomerate (d$^{2''}$), which is excellently exposed in a small cliff on the left bank of the stream.

The matrix of this conglomerate is similar to that of the under-

lying sandstone, consisting of rounded fragments of felstone and quartz imbedded in a greenish dust. But it is, in addition, highly calcareous along certain laminæ, and presents that peculiar mode of weathering into concentric flakes so common among basaltic dykes. The included pebbles are of quartz and several varieties of volcanic rocks, and are collectively of the same general type as those of the underlying Benan Conglomerate.

Lying buried in the sandier part of the matrix, and often scattered through the coarsest part of the conglomerate itself, occur many poorly preserved fossils. The most frequent are corals and those Brachiopoda whose shells are composed of carbonate of lime, both of which groups are practically wanting in the hard Balclatchie mudstones below. The commonest forms are:—

Lindstrœmia, several species.	Leptæna sericea, *Sow.*
Fistulipora favosa, *N & E.*	—— transversalis, *Wahl.*
Strophomena corrugatella, *Dav.*	Bellerophon, &c.
Leptæna quinquecostata.	

The conglomerate passes upwards into a series of dark green ashy sandstones ($d^{2'''}$), identical in petrological character with those below, but generally thicker-bedded, and having about twice their vertical extent. They contain a few fossils of the same type as those of the underlying conglomerate.

These green gritstones are well shown in the bed of the burn, lying at a medium angle upon the ashy conglomerate, where an old hill-road fords the stream. Immediately beyond, they are succeeded by the thick masses of dark flaggy shales and mudstones which form the bed and bounding walls of the gorge for a long distance below this locality, and which compose the first member of the overlying Ardmillan Graptolitic series (Ba), which falls to be described in the following section of this memoir. At the junction of the two groups, however, occurs a peculiar transitional band which must here be noticed. It consists of a few feet of iron-stained shales, with seams of hard calcareous and concretionary rock. The shales contain abundant Graptolites of the species

Cryptograptus tricornis, *Carr.*	Diplograptus foliaceus, *Murch.*, &c.;
Lasiograptus Harknessi, *Nich.*	

while the calcareous band yields a few examples of Brachiopoda, chiefly

Leptæna corrugatella,	Orthis calligramma, &c.

We learn, therefore, that in this special locality the Benan Conglomerate becomes interstratified with fossiliferous mudstones at its summit; and what may be regarded as its final member, from a physical point of view, is a thin series of green gritstones, which are divided from the typical boulder-beds of the great conglomerate below by a group of fossiliferous shales. The general identity of the matrix and enclosures of the gritstones with those of the Benan Conglomerate is suggestive of the natural union of the gritstone group with the Barr or Stinchar series, rather than with the succeeding Graptolitic flagstones of the Penwhapple. The

dividing fossiliferous shales point in the same direction; for petrographically they are almost identical with those of the *Didymograptus*-beds which *underlie* the great conglomerate, while they are very different from the hard flaggy Graptolitic shales of Penwhapple. As will be demonstrated in the sequel, the palæontological evidence is even more strongly in favour of the union of these gritstones and shales which together make up our group of the *Balclatchie Beds*, with the Stinchar or Barr group; for the majority of the forms known from these beds are identical with those of the Craighead limestone.

This fossiliferous group of gritstones and shales is therefore placed, in our scheme (see Table, fig. 31, p. 661), at the summit of the Barr or Stinchar Series, which constitutes the first great division of the Girvan succession, and embraces the whole of the strata lying between the base of the Kirkland Conglomerate and the summit of these Balclatchie Beds.

2. *Barbae, &c.*—The line of boundary between the great sheet of Benan Conglomerate and Graptolitic flagstone, ranging from Balclatchie Bridge to the neighbourhood of Millenderdale, has been carefully searched by myself for traces of the Balclatchie Beds; but such exposures as do occur are very fragmentary and unsatisfactory.

These highly distinctive and continuous sheets of strata are apparently separated from each other along the whole of this extent by an intermediate band of mixed character. Long tongues of hard gritstone and breccia run irregularly into the edges of the area of Graptolitic flagstones; and irregular patches of concretionary shales and dark Graptolitic mudstones destroy the regularity of the margins of the area of the Benan Conglomerate.

Broadly speaking, this intermediate band is largely composed of the green grits and fossiliferous mudstones of the Balclatchie Beds. On the Doon Hill, they lie apparently in a sharp synclinal in the conglomerate itself, while the fossil-bearing shales are again exposed in the roadway between the Dhu Craig and the water of Assel. At the angle of the same road about half a mile south-west of the farmstead of Balclatchie, the green fossiliferous gritstone and conglomerate are seen, containing a few shells, associated with green concretionary and dark laminated Graptolitic mudstones, and clearly interposed between the Benan rock of the east bank of the stream, and the sheet of flagstones seen in the numerous quarries opened for repairing the roadway.

Between this locality and the farmhouse of Pinmery there are numerous exposures of the Balclatchie Beds. In the steep slopes of the Assel, about a quarter of a mile west of Pinmery, the highest beds of the Benan Conglomerate are seen to the north of the Tramitchell fault in several quarries and natural exposures. They are harder than usual, and the matrix is more of the nature of a coarse greywacke. The included boulders are of great size, and are scattered irregularly through the mass of rock, in which few small pebbles are visible. Immediately above them the concretionary and shaly Balclatchie mudstones are seen in many isolated spots. They are succeeded at once by coarse green partly conglomeratic

gritstones, which pass upwards into the basal beds of the Graptolitic flagstones that fill the extended area to the north.

A short distance to the south-west we find a magnificent exposure of these conglomeratic grits near the lime-quarries of Tramitchell. The extended area of Graptolitic flagstone is there bounded to the southward by a band of coarse pebbly grit, about 50 feet in thickness, which extends in an unbroken line from Pinmery to the north flank of Dalfask Hill, a distance of more than a mile and a quarter.

At its eastern extremity it is seen in a shattered state in the roadside quarries about a hundred yards from the lime quarry. It there consists of a mass of sandy gritstones filled with small pebbles of quartz, greywacke, and various species of igneous rocks, and it is associated with distinctly bedded greywackes and shales of the usual type. Fossils are procurable with difficulty, mainly *Leptæna sericea*, with a few Lamellibranchiata and fragments of Encrinites.

In the road-side close to the farmhouse of Barbae the grit is well exposed to view in the hill-face and roadway. It there abounds in fragments of quartz, and, except for its decidedly gritty matrix, has few points of resemblance to the typical Balclatchie grit. It contains a few fossils in some shaly seams at its summit. *Leptæna, Bellerophon* and *Ctenodonta* were here collected by myself.

At its westernmost termination the grit is exposed in some old quarries west of the Dalfask burn. In this locality it is identical in composition and texture with the Barbae bed, but is weathered to a greyish yellow tint, and is apparently more fossiliferous than usual, containing many fragmentary examples of *Leptæna*, *Lindstrœmia* and Encrinites.

Crossing the broad sheet of Benan Conglomerate exposed in the hill of Dalfask and the valley of the Assel, we again come upon the Balclatchie transitional beds on the ridge of Daldowie Hill. They occupy their normal place between the Benan Conglomerate and the great mass of the Graptolitic flagstones, which here stretch in unbroken mass for many miles southwestward, across the lower valley of the Assel, into the heart of the igneous region of Lendal Water. The numerous exposures of the transitional beds shown upon the hill-face west of the mountain-road from Pinmore to Minuntion present us with phenomena identical with those afforded by the corresponding geographical band between Balclatchie and Pinmery. The highest beds of the Benan Conglomerate are gritty and abound with quartz pebbles, varying in size from that of a bullet to that of a man's head. These beds are repeated in anticlinal folds again and again; and in the synclinals between them occur the concretionary and Graptolitic mudstones and the coarse green sandy rocks of the Balclatchie Beds. In one or two spots the shales, which often weather to a yellowish drab colour, afford many small shells, of the general type of those of Balclatchie, such as *Strophomena corrugatella*, Dav., *Leptæna sericea*, Sow., together with *Ctenodonta* and a form of *Ampyx*.

3. *Ardmillan Braes.*—The numerous sections of the Balclatchie group we have last noticed are all greatly deficient in recognized organic remains. In all probability this is mainly due to the

fact that they lie out of the usual track of fossil-collectors. But, with the exception of the thin seams on Daldowie Hill, few of the localities would repay an extended study; for fossils, though certainly present, seem generally to be rare.

In the fine exposure of the same beds near the shore at Ardwell, next to be described, fossils are remarkably abundant, and are specifically even more crowded than in the typical shales of Balclatchie Bridge.

The great mass of Benan Conglomerate, which reposes upon the igneous and metamorphic rocks of Penbain and the Grey Hill, and stretches in a continuous sheet from Kennedy's Pass to the rugged mound of the Byne Hill, plunges at a steep angle below the great mass of Graptolitic flagstones of Ardwell shore. The line of junction between the conglomerate and flagstones is obscured for the greater part of its extent; but for a limited distance about the centre of its range the intermediate Balclatchie Beds are seen in some old quarries in the hill-face above Ardwell farm, and in the steep burn-course of the little stream which passes the ancient castle of Ardmillan.

In the old road which ascends the heights southeastward from the farm of Ardwell, the Graptolitic flagstones are seen striking from S.W. to N.E., and dipping at a steep angle seaward. On the heights above, the Benan Conglomerate is easily identified, having all its usual characters, and coinciding in its range with the more recent Graptolitic flagstones below. Midway between these two exposures, and thus occupying their usual intermediate geographical and geological position, the green concretionary mudstones of Balclatchie are visible in several quarries, trending in precisely the same general direction as the conglomerate and flagstones which enclose them. Some small streamlets which run past the quarries have trenched the superficial coating of the hill sufficiently to allow us to make out the details of the succession from the fossiliferous mudstone into the heart of the great Conglomerate.

Commencing at the summit of the section, we notice that some 40 or 50 feet of the Benan Conglomerate are exposed. The matrix has the usual gritty character of the upper beds of the formation. and shows the normal preponderance of porphyrite and quartzite pebbles.

In immediate contact with the conglomerate, but dipping almost vertically in the opposite direction, occur some 20 feet of coarse well-bedded gritstones, with a greenish grey interior, but weathering to a purplish tint upon their edges. These are succeeded by a slightly greater thickness of calcareous sandstones, abundantly fossiliferous upon several horizons. They contain *Remopleurides dorsospinifer*, *Asaphus gigas*, *Staurocephalus globiceps*, *Phacops Brongniarti*, *Orthis calligramma*, *O. Actoniæ*, *Leptæna tenuicincta*, *Murchisonia*, and all the characteristic Balclatchie fossils.

After a short interval of concealment we reach the green concretionary mudstones, of which 60 or 70 feet are exposed in the quarries and in the natural sections. In their mineralogical characters they are identical with the shell-bearing beds that follow immediately upon the Benan Conglomerate in our typical exposure at Balclatchie

Bridge, having the same concretionary structure, and being equally difficult of disintegration under the hammer. The fossils, too, are preserved precisely in the same manner; the majority are found in perfect relief, the chitinous forms with highly polished surfaces, and the Testacea with their shells often beautifully preserved.

The commonest forms that meet the eye of the collector in these shales are identical with those of the green mudstones of Balclatchie, The following are especially numerous:—

Theca reversa, *Salt.*	Strophomena, sp.
Bellerophon acutus.	Rhaphistoma, sp.
Modiolopsis, sp.	Dicranograptus tardiusculus.
Leptæna tenuicincta.	Didymograptus moffatensis.
—— sericea.	Cyclonema crebristria.

The Graptolitic flagstones of Penwhapple are not exposed at this locality, with the exception of the basal calcareous and carbonaceous band, which yields its usual Lasiograptidæ in good preservation.

The relation of the fossiliferous Balclatchie Sandstones to the Benan Conglomerate at this locality is presumptive of a dislocation between the two: and if the natural sequence contains the same members here as at Balclatchie, the beds here in contact with the conglomerate must be the highest beds—the fossiliferous mudstones being the lowest strata of the transitional groups here exposed, and owing their great thickness to their being arranged in anticlinal form. The hiatus in the succession would naturally be filled by the Graptolitiferous mudstones, over which follow the shell-bearing gritstones in their proper sequence.

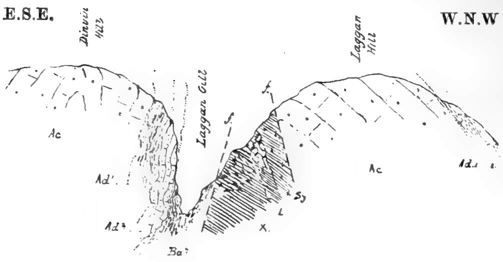
If this be the true interpretation of the visible phenomena, it follows that the shell-bearing gritstones should be repeated between these quarries and the Graptolitic flagstones visible in the roadway, or must be again cut out by a fault. That the latter supposition is in all probability the correct one is evident from the fact that where the sequence is unbroken, a quarter of a mile to the westward, it is identical with that at Balclatchie, as is also the case in Ardmillan Burn about half a mile further to the east.

4. *Ardmillan Burn.*—In the steep and narrow gorge excavated by the little burn of Ardmillan a continuous section is laid bare from the Benan Conglomerate into the heart of the Graptolitic flagstones. The Balclatchie beds themselves yield many of the same fossils as those found at Ardmillan Braes; but the phenomena they present afford us little worthy of notice as respects the stratigraphy of the group.

5. *Laggan Gill.*—In the narrow glen which separates the two masses of Benan Conglomerate that cap the points of Laggan Hill and Glendrissoch, the Balclatchie Beds are displayed in the banks of the small streamlet which passes the old hamlet of Laggan.

The section here is, in many respects, a most remarkable one. The structure will be understood from the accompanying section (fig. 15). The Balclatchie shales and gritstones are seen in inverted position in the cliffs to the west of the little gorge, and yield a few of the usual fossils, which, however, are procurable with

Fig. 15.—*Section at Laggan Gill.*



Ba². Basal zone of Graptolitic flagstones—soft shales, with *Lasiograptus, Cryptograptus, Trachyderma*, &c.
Ad². Balclatchie grits and flagstones.
Ad¹. Balclatchie mudstones, much broken.
Ac. Benan Conglomerate.
Ballantrae Rocks:—
Sy. Syenitic rock.
L. Calcareous rock shattered and altered.
* Altered breccias.

difficulty. This is nevertheless by no means the case with the peculiar transitional zone at the summit of the group, which occurs here in its normal position at the base of the Graptolitic flagstone series. Its strata, although greatly folded, are crowded with the characteristic Graptolites and Brachiopoda in a state of exquisite preservation.

The commonest forms are *Cryptograptus tricornis*, Carr., *Lasiograptus Harknessi*, Nich., *Climacograptus bicornis*, Hall, *C. Scharenbergi*, Lapw., *Diplograptus rugosus*, Emm., *D. foliaceus*, Murch., together with species of *Trachyderma, Cythere*, &c. &c.

This Balclatchie band is prolonged to the south-eastward of Laggan Gill, along the northern margin of the conglomeratic area of Dinvin and Dalfask, into the neighbourhood of Barbae and Tramitchell, where it has been noticed already.

6. *Dow Hill.*—Upon the inlier of Dow Hill (see map, Pl. XXV.) the Balclatchie mudstones, which there repose in their natural place upon the Benan Conglomerate, have yielded to the persevering researches of Mr. Robert Gray a large suite of fossils, identical with those of the typical locality and of Ardmillan Braes. The same Balclatchie zone is met with in a corresponding position at several spots on both margins of the Pinmore synclinal, while the overlying transitional seam (Ba^n) occurs at various localities within the same area, and is abundantly fossiliferous. It is needless to enter into further details of these exposures.

Summary.—The strata which next fall to be described are the Graptolitic Flagstones and Shales of Ardwell and Penwhapple. These, however, are so distinct in their lithological and palæontological features from the rocks already noticed, that it is impossible to place them in the same systematic group. We are therefore

forced to regard the first major formation or division of the Girvan Succession as being terminated above by the final zone of the Balclatchie Beds last described, the overlying Graptoliferous flagstones and shales of Ardwell forming the first member of a second and succeeding division.

The facts adduced in the preceding pages render it absolutely certain that the great Benan Conglomerate (Ac), which we originally selected as our general horizon of reference, is everywhere *underlain* by the Stinchar Limestone (Ab), and its associated basal conglomerate and sandstone of Kirkland and Craighead, and everywhere *overlain* by the transitional zone of Balclatchie (Ad). From the base of the Kirkland Conglomerate to the summit of the Balclatchie Beds, the sequence is demonstrably continuous; while the various fossiliferous subformations are united by a general community of organic remains. We therefore regard the strata within these limits as collectively constituting the first recognizable major division or formation in the Girvan Succession.

To this primary division we assign the title of the *Barr Series*, after the name of the village where its strata are most effectively displayed to the investigator. The entire division may be broadly defined as a series of conglomerates and boulder-beds, relieved by zones of limestone, sandstones, and fossiliferous shales. Its component subformations, as we have seen, vary greatly in thickness, even within the limits of the Girvan region; but they everywhere retain the same stratigraphical interrelations, lithological features, and characteristic organic remains.

The ascending order among the several members of the Barr Series is given in the following Table:—

A. Barr series. (700 to 1000 feet.)

Aa. Kirkland or Purple Conglomerate and Sandstone	30–200 feet.
Ab. Stinchar or Craighead Limestone Group	100–150 „
Ab[1]. *Orthis-confinis* flagstones.	
Ab[2]. *Maclurea*-beds.	
Ab[3]. Compact Limestones.	
Ab[4]. *Didymograptus*-shales.	
Ac. Benan or Green Conglomerate	500–600 „
Ad. Balclatchie Beds	80–100 „
Ad[1]. Balclatchie Mudstones.	
Ad[2]. Balclatchie Grits and Conglomerate.	

(b) *Description of the Typical Section of the Graptolitic-flagstone Series of Ardmillan Shore.*

As we have already pointed out, the great Barr or Stinchar series, which is terminated above by the fossiliferous zone of the Balclatchie beds last described, is bounded everywhere on its northern or upper margin by a group of flagstones which occupy collectively a continuous area equal in geographical extent to that filled by the Stinchar series itself. The ground occupied by these flagstones extends northward from the margin of the Benan Conglomerate to a line of fault which ranges from the coast-line south of the town of Girvan across Saugh Hill inland to the Old-Red-Sandstone heights

of Hadyard and Garleffin. Throughout this extended area these beds consist essentially of thin-bedded flagstones and shales, with occasional zones of sandy and pebbly grit. Where they become carbonaceous they contain an abundance of Graptolites, generally, however, of few species. A few calcareous seams are met with at intervals; and these yield fragmentary Trilobites, Cephalopoda, and Brachiopoda. The whole of the beds are thrown into innumerable folds and contortions, are frequently inverted, and are much dislocated by local faults. But the lowest beds everywhere distinctly repose conformably upon the great sheet of Benan Conglomerate, from which they graduate through the transitional zone of the Balclatchie Beds. This fact, as we have shown, holds good, not only with respect to the main mass of conglomerate itself as seen at Balclatchie, but also in the many disconnected exposures of the same rock in the hills of Barlae, Laggan Gill, and in the terminal strip of Benan Conglomerate which descends from the Ballantrae rocks of Grey Hill, and runs out to sea in the headland of Kennedy's Pass.

It is in the last of these localities that the succeeding Graptolitic series is most completely exposed to the inspection of the stratigraphist and palæontologist. Its strata constitute the floor of the old raised shore-terrace of Ardmillan and Woodlands, and are truncated obliquely by the sea along the rocky coast-line between Kennedy's Pass and the hamlet of Shalloch, for a distance of about three miles.

An almost continuous section of the beds is laid bare along the shore throughout the whole of this extent. The strata run out to sea in a low platform which is never entirely covered by the waves and is wholly exposed to the investigator at low tide.

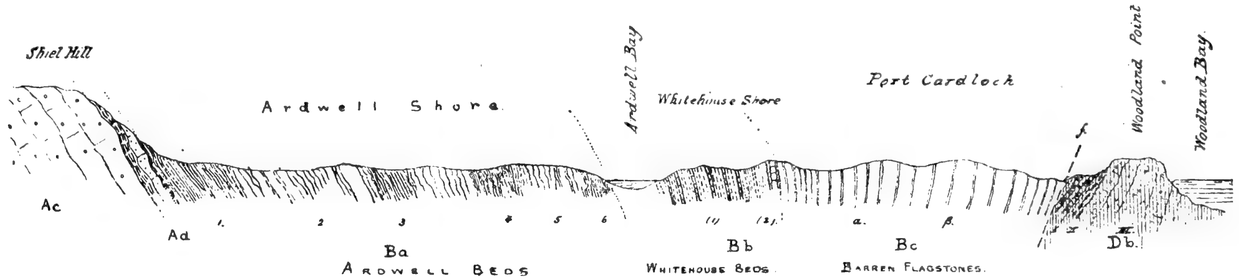
The main highway from Girvan to Ballantrae is carried along the seaward edge of this platform: so that the student of the geology of the district enjoys exceptional advantages in the study of the flag-like Graptolitic deposits of this locality.

The most conspicuous object upon this raised platform is the ancient house of Ardmillan, the seat of the proprietor of the neighbouring estate. It lies at the foot of the wooded slopes of Mains Hill, and about the centre of the area occupied by the flagstone group. This circumstance has suggested to me the title of Ardmillan Group as a collective name for the flagstone series, a title which marks definitely the special locality where its strata are most satisfactorily exposed.

A section drawn transversely across the rocks of this area displays the succession shown in the accompanying figure (fig. 16). The elevated heights of Mains Hill and Grey Hill are formed of the bedded and intrusive rocks of the Ballantrae region—syenitic, dioritic and felspathic. Upon these, inclined at a steep angle, leans the great sheet of Benan Conglomerate and its associated Balclatchie beds, extending to the shore-line in the cliffs of Kennedy's Pass. This occupies all the higher portions of the northern slopes of these hills, and ranges downwards to the edge of the cultivated grounds of Ardmillan and Ardwell.

1. *Ardwell Shales and Flags.*—The Conglomerate series is succeeded

Fig. 16.—*Typical Section of Ardmillan Shore.*



Db. Woodland Beds.
- III. Coarse yellow grits, flagstones, and conglomerates.
- II. Striped carbonaceous shales, with *Climacograptus rectangularis* and *Monograptus tenuis*.
- I. Calcareous flags and limestone (Lower *Pentamerus*-limestone), with *Stricklandinia lens, Pentamerus oblongus, Encrinurus punctatus*, &c.

Bc. Barren or Shalloch flagstones.
- β. Thick-bedded flagstones, with partings of green shale and mudstone, barren of fossils.
- a. Thick-bedded shales and mudstones, with ribs of hard grey flagstones, *Nematolites Grayii*, &c.

Bb. Whitehouse beds.
- (2). Upper division—green and purple mudstone and thin-bedded flags, with calcareous and carbonaceous seams: *Dionide Lapworthi, Æglina rediviva, Dindymene*, sp., *Dictyonema, Dicellograptus complanatus, Diplograptus socialis.*
- (1). Lower division—grey flaggy shales, with thick ribs and bands of calcareous grit, affording *Leptæna sericea, L. transversalis*, &c.
- (x). Basal shales crowded with *Dicellograptus Forchhammeri* &c.

Ba. Ardwell beds.
- 6. Thin-bedded flaggy shales, crowded with *Climacograptus caudatus* &c.
- 5. Flaggy beds, with *Dicranograptus ramosus* &c.
- 3, 4. Splintery shales, iron-stained, with *Corynoides calycularis* &c.
- 2. Thick-bedded hard grey flags, with partings of hard striped shales; fossils rare, principally *Diplograptus rugosus*, Emm.
- 1. Hard slaty shales and nodular striped mudstones, carbonaceous, ferriferous; fossils rare.

Ad. Balclatchie beds.
(Faulted out of shore section; seen *in situ* upon heights above Ardwell Farm.)

Ac. Benan Conglomerate.

immediately by the basal division of the great overlying Graptolitiferous series. The lowest beds of this division are well exposed in several natural and artificial excavations along the line of section, in a magnificent and unbroken cliff-section between the farm of Ardwell and the rocks of Kennedy's Pass, and in the sides of the narrow gorge dug out by the little stream of Ardmillan itself.

The inferior zones of this lowest division of the Flagstone group may be seen dipping off the Balclatchie Beds in the gorge of Ardmillan and in the slopes of the neighbouring heights, while they agree everywhere in strike and inclination with the underlying group.

The middle beds are best exposed in the coast-section south of Ardwell, where they can be studied foot by foot in the continuous exposures washed by the sea-waves. The lowest beds are thin-bedded shales, of a dark grey colour, with a few seams or ribs of hard grey rock. They are more or less carbonaceous, and weather with a rusty exterior. They yield a few Graptolithina, chiefly *Diplograptus foliaceus*, Murch., *D. pristis*, His., *D. rugosus*, Emm., *Climacograptus bicornis*, Hall. Higher up, the rocks become rapidly coarser and more flag-like in their character, until in their highest zones near the farm of Ardwell they may be described as a series of dark-grey flagstones from four to six inches in individual thickness, separated by partings of dark grey shale. The same fossils are here met with as in the lower zones, and, in addition, *Dicranograptus ramosus*, *Corynoides calycularis*, *Ecculiomphalus Bucklandi* and an occasional Brachiopod. The highest zone is formed of striped shales crowded with hosts of *Climacograptus caudatus* and *Diplograptus rugosus*. The exposure of these beds is terminated suddenly by the sandy bay of Ardwell; and the rocks which next make their appearance are the lowest zones of the succeeding group.

Although the oblique section of the Ardwell shales and flags upon the coast here between Kennedy's Pass and the farmland of Ardwell exceeds a mile in length, the actual transverse breadth of the zone is less than one fourth of a mile, so that at their average inclination of about 70° or 80° the thickness of the Ardwell Beds here exposed cannot exceed 1000 feet. It is more than doubtful, however, if the entire thickness of the Ardwell Beds is here developed, as the hiatus in the bay probably marks the position of a line of fault that cuts out a group of flaggy sandstones and grits (Cascade Beds, compare p. 606), which appear to constitute the higher parts of the Ardwell Beds in the interior of the country.

The Ardwell Beds, as seen in this typical locality, are much more intensely hardened than is generally the case in the inland sections, and fossils are rarer and more difficult of extraction. The group is well characterized, however, by its peculiar petrological features. Wherever a transverse section of beds is laid open, the strata are seen to be normally formed of thin seams of alternate grey and black or blue laminæ. This gives to the beds a somewhat striped appearance, which is most characteristic. The quantity of carbonaceous matter present is comparatively large; and iron is sufficiently

abundant to cause the entire series to weather to a deep rusty colour.

2. *Whitehouse Beds.*—Crossing the sandy floor of the small bay of Ardwell, already referred to, where there is a break in the section of about 100 feet in calculated thickness, we enter next upon a group of strata of a totally distinct petrological character. This new group has here a collective thickness of about 200 feet; and its strata are easily studied at many points along the coast-line between Ardwell and Shalloch Mill. Their entire thickness, however, is shown only in the present locality, along the shore-line between Ardwell Bay and the old ruin of Whitehouse, which is built upon them, and after which I have named them.

These Whitehouse Beds consist of a series of shales and mudstones, of colours varying from bright red and purple to greyish green and black, and showing numerous intercalary ribs and zones of grey flagstone. But by far the most characteristic feature of the formation is the frequent presence of impure calcareous bands or "cement-stones," crowded with fragmentary Brachiopods and Trilobites.

The entire group falls very naturally into two main divisions—a *lower* division of grey shales and striped flagstones, and an *upper* division of purple and green mudstones.

Lower Whitehouse Beds (Bb^1).—The basal band of this subgroup is formed of striped grey and green somewhat carbonaceous shales, much softer than those of the underlying *Ardwell* group, from the terminal beds of which they are divided by the sandy beach of Ardwell Bay. They contain abundant examples of *Dicellograptus Forchhammeri* &c.

The middle subdivision is characterized as a whole by the presence of numerous ribs of calcareous matter, filled with small pebbles, and yielding a few fragmentary Brachiopoda. These calcareous zones are imbedded in masses of barren greenish-grey flagstones, separated by striped shales destitute of all traces of organic remains.

The commonest fossils I have been able to collect from these cement-beds are:—

Leptæna transversalis.	Orthis calligramma.
—— sericea, *Sow.*	Strophomena, sp.

As we ascend the succession the hard flaggy ribs become more closely approximated, but otherwise the character of the beds remains essentially unmodified for about 100 feet of thickness.

They are followed by a final group of some 50 or 60 feet of strata of a most peculiar character. These consist of soft green mudstones, filled with a multitude of hard siliceous ribs, about an inch in thickness and one or two inches apart. The action of the sea-waves has dug away the soft mudstones to some depth, leaving the intervening hard ribs projecting in long jagged parallel lines upon the floor of the sea-platform, giving a most striking appearance to the little group as here exhibited.

Upper Whitehouse Beds (Bb^2).—Next succeeds the *Upper* and most

characteristic division of the Whitehouse beds. It consists of about 80 feet of brightly coloured mudstones, shales, flags, and calcareous beds, remarkable not only for their unique petrological features, but also for the variety and abundance of their organic remains.

The lowest beds of the division consist of 15 feet of dark-green mudstones, filled with lines and bands of purple shale. They are succeeded at once by a thickness of about 30 feet of soft mudstones of a brilliant purple colour. These are soft and easily disintegrated, and have here been worn away by the sea-waves into a deep hollow between the underlying and overlying intractable grits and flagstones. They are totally barren of fossils throughout. So far as can be made out by piecing together the greatly shattered beds at this spot, they pass insensibly upwards into a particoloured zone of mudstones, about 15 feet thick, purple and green like those at their base, and equally barren of organic remains.

Finally we have a zone of 20 feet, hard flaggy beds, of which only disconnected patches are visible at this locality. These consist of flaggy-looking and sandy beds, which stand up on edge amid the sea-waves as several prominent bosses, and are only accessible at low tide. They are almost wholly composed of platy shales and flagstones, more or less calcareous, striped by thin seams of carbonaceous matter, and including several highly fossiliferous seams crowded with fairly preserved Trilobites and Graptolithina.

The commonest forms I have procured from these beds at this locality include:—

Dionide Lapworthi, *Eth. jun.*
Cyclopyge rediviva, *Barr.*
—— armata, *Barr.*
Dindymene, sp.
Agnostus perrugatus, *Barr.*
Turrilepas Peachii, *Eth. jun.*
Dicellograptus Morrisi, *Hopk.*
—— complanatus, *Lapw.*
Diplograptus socialis, *Lapw.*
Climacograptus tubuliferus, *Lapw.*
Dictyonema.
Ganocladium.

This fossiliferous zone is succeeded immediately by the thick-bedded flagstones of the overlying Barren-flagstone group (Bc), to be noticed later on. Only a few feet, however, of these overlying flagstones are here exposed to view, and their description is best deferred until we have completed our study of the distribution of the Whitehouse Beds along the coast-section of this neighbourhood.

It will be apparent on a study of the map (No. 3, Pl. XXV.) that these Upper Whitehouse Beds, with their remarkable seams of purple shales and ribbed mudstones, can be followed as a continuous band running along the general line of the coast from Whitehouse to the mouth of the Byne-Hill Burn, for a distance of about a mile. They are much interfered with locally by small dislocations; but the continuity of the band is never actually interrupted, throughout its entire length.

At the head of Port Cardloch, close to the lodge-gate of Ardmillan House, some of these local dislocations are well shown; and a thin set of hard green conglomeratic grits makes its appearance at the base of the series, forming a conspicuous vertical wall of rock.

After crossing the cultivated angle of Woodland Point, we again

come upon the band of purple and green mudstone in Woodland Bay. Here only a few feet of the ribbed shales are discernible, projecting from the sand of the beach; but there seems to be a fairly unbroken section from these ribbed beds into the basal beds of the succeeding Barren-flagstone group, through the purple mudstones and *Dionide*-seams, though only a few fragmentary Graptolites are obtainable among the shattered and sodden strata.

For the next quarter of a mile the Whitehouse Beds are generally hidden from sight below the sandy beach of Woodland Bay; but where they next put in an appearance, viz. in Myoch Bay, upon the shore-line near Shalloch Mill, we have by far the most complete and satisfactory exposure of their upper zones in the Girvan district.

The geographical relations of these beds upon the ground are given in the following sketch plan (fig. 17); and the interrelationship of the various component zones will be evident upon a study of the accompanying section.

Myoch Bay.—The deepest strata shown in the continuous section laid open from S. to N. across the exposure in the floor of Myoch Bay, are the coarse, thick-bedded and gritty sandstones recognized by us in the faulted patch at Port Cardloch. Next succeed the green shales, with ribs of harder and gritty flags. Of these at least about forty feet are exposed, forming some jagged reefs to the right of the little grassy headland south of the bay.

Above follows the first band of the Upper Whitehouse group, consisting of about 15 feet of soft green mudstones and shales, with lines of purple mudstone. These are easily followed for some distance round the corner of the little headland to the south, much interfered with, however, by numerous longitudinal and transverse faults.

The central parts of the bay are wholly occupied by the Upper Whitehouse Beds. To the S.E. lies the zone of purple mudstones. These are bent into innumerable folds and wrinkles, and are dug out into the usual broad hollow. It is difficult to estimate their thickness; but this cannot be more than about 30 feet. They are followed to the north by the second transitional zone of green mudstones with purple seams, which passes upwards into the fossiliferous division that terminates the banded series. These Upper transitional beds have an estimated thickness of about 20 feet.

The final or fossiliferous subgroup is greatly contorted and broken; but when carefully mapped in detail the following succession is easily made out:—

(1) *Dicellograptus complanatus* zone. Black shales, highly carbonaceous, with a few seams of grey mudstone and calcareous grit, crowded with Graptolites (5 feet).

Diplograptus socialis, Lapw., is the commonest form, and occurs in hosts. Less frequent are the forms named in the following list:—

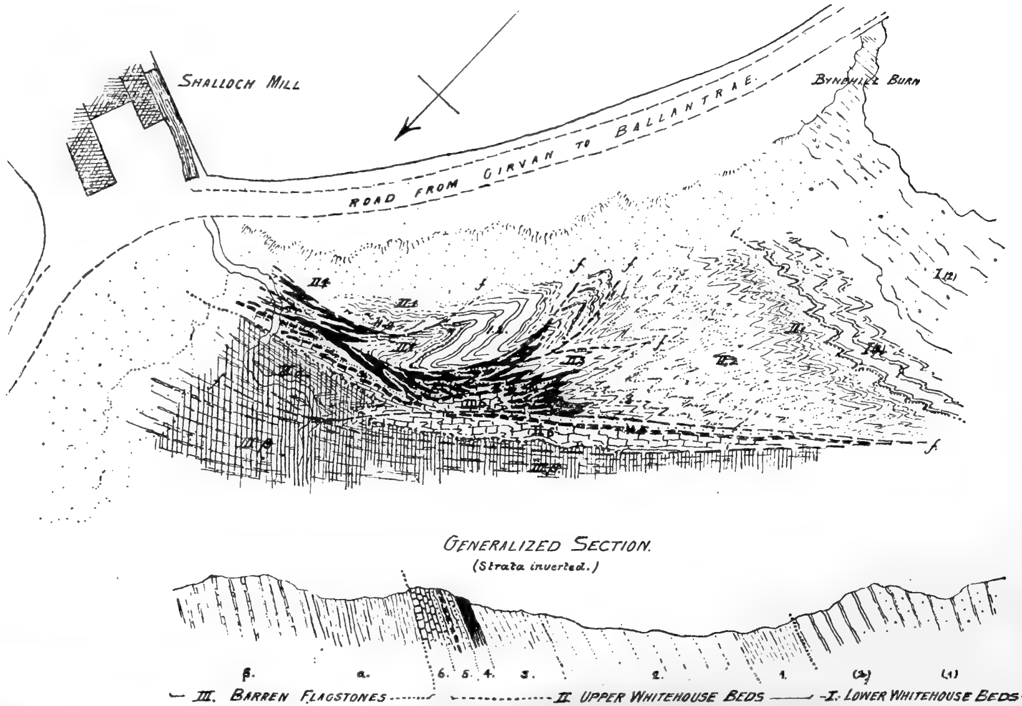
Climacograptus tubuliferus, *Lapw.*
Dicellograptus complanatus, *Lapw.*
—— Morrisi, *Hopk.*
Theca triangularis, *Portlock.*
Lingula.

Fig 17.—*Plan and Section of Exposure at Myoch Bay.*

III. Barren Flagstones.
- β. Flaggy grey shales with ribs of grey flagstones.
- a. Thin shales and mudstones, with *Nematolites Grayii, Dicellograptus Morrisi*, &c.

II. Upper Whitehouse Beds.
- 6. Nodular, grey, calcareous mudstones, highly fossiliferous—*Trinucleus, Illænus, Agnostus, Dionide*, &c. (*Dionide*-band).
- 5. Flaggy shales, with hard calcareous ribs—*Dictyonema, Ganocladium*, &c. (*Dictyonema*-bed).
- 4. Black carbonaceous shale, crowded with Graptolites—*Dipl. socialis, Dicello. complanatus* (*D. complanatus*-bed).
- 3. Transitional zone of banded purple and green mudstones and shales.
- 2. Purple mudstone, barren of fossils.
- 1. Transitional zone of banded purple and green mudstones and shales.

I. Lower Whitehouse Beds.
- (2). Green shales and mudstones, with ribs of hard grey flagstone.
- (1). Grey and green shales, flags, and thick-bedded grits.



(2) *Dictyonema*-zone.—Hard flaggy shales (9 feet), with ribs of grey calcareous rocks. In certain zones these beds contain an abundance of *Dictyonema*, together with numerous fragments of Phyllopoda, Lingulidæ, and Diplograptidæ.

The characteristic forms are *Dictyonema*, *Ganocladium*, *Lingula*.

(3) *Dionide*-beds.—Finally we have a thickness of about 6 feet of mudstones, containing such a large proportion of calcareous matter that in places they rather deserve the title of impure nodular limestones. They afford a large and varied association of fossils, some of which are beautifully preserved.

The commonest collected from these beds by Mrs. Gray or myself include :—

Trinucleus seticornis, *His.*	Murchisonia.
Asaphus, sp.	Bellerophon.
Illænus Bowmanni, *Salt.*	Ctenodonta.
Agnostus perrugatus, *Barr.*	Orthonota.

Before terminating the description of the Whitehouse-Bay beds at this locality, mention must be made of the section visible in the lower reaches of the Byne-Hill Burn, which empties itself into Myoch Bay a few yards to the south-west of the locality we have last noticed in detail. These beds are exposed in the stream-course near its mouth, and are of the same general character as those of the majority of the Whitehouse group, to which they unquestionably belong; but the absence of definite ribs of flagstone from among the soft blue shaly mudstones of which these Byne-Burn beds are made up, will not allow us to parallel the little group satisfactorily with any of the zones already described. In the Byne-Hill Burn they consist of about 100 feet of soft blue flaggy mudstones, arranged in thin beds, and striped with numerous seams of carbonaceous matter.

They contain some well-preserved Graptolites, viz. :—

Leptograptus flaccidus, *Hall.*	Diplograptus quadrimucronatus, *Hall.*
Pleurograptus linearis, *Carr.*	—— foliaceus, *His.*
Dicellograptus Morrisi, *Hopk.*	Climacograptus tubuliferus, *Lapw.*

The Myoch-Bay and Byne-Hill-Burn exposures are the final exhibitions of the Whitehouse Beds in this locality, the strike of the strata carrying them inland beneath the cultivated flats of Shalloch and Ballochmyle.

3. *Barren Flagstones of Shalloch Mill.*—The band of purple and grey fossiliferous mudstones of the Whitehouse Beds last described is succeeded to the northward, throughout the whole extent of its range from Whitehouse to Myoch Bay, by a thick series of shales, flagstones, and greywackes of a dull greyish-green colour, generally destitute of all trace of unequivocal fossil remains (III., fig. 17). The breadth of this Barren-flagstone group upon the ground at its widest horizontal extension (as near Woodland Point) is about 200 yards. As the beds are nearly perpendicular, this would give the group an approximate thickness of about 500 feet.

For the first 50 feet of their thickness the Barren-flagstone strata

consist of pale-green mudstones and very thin flags, having the same general dip and strike as the underlying Whitehouse Beds, out of which they graduate conformably. These shaly beds contain frequent examples of the enigmatical fossil *Nematolites Grayii*, a form that preeminently distinguishes this group throughout the Girvan region.

As we ascend in the succession, thick beds of flagstone gradually make their appearance among the mudstones, with which they agree exactly in their colour and composition, but are somewhat coarser and more compact in texture. At first these ribs of flagstone occur regularly at intervals of about 3 feet, and are usually not more than a foot in thickness. When we have overpassed the central line of the group, however, the ribs rapidly increase both in abundance and in individual thickness, so that finally they become, physically, much more important than the mass of soft shales and mudstones in which they are intercalated. Many of these flaggy beds attain here a thickness of from 3 to 4 feet, while the intermediary shales have dwindled down to a few inches. Near the summit of the group, however, as exhibited along the coast-line, the flags again become thinner and less conspicuous, and the shales regain their normal importance in the succession.

This band of Barren Flagstones forms a conspicuous feature on the surface of the coast-section, both eastward and westward from their typical exposure in Woodland Bay. They are well displayed in both sides of Port Cardloch, following immediately upon the fossiliferous zone of the Whitehouse Beds, their hard ribs standing up perpendicularly on the rugged coast-platform, divided from each other by the deep grooves from which the soft intercalary shales have been eroded. In Whitehouse Bay also they are shown in the same geological position; but only a few feet of their lowest zones are exposed, even at low water.

They form two small islands in Woodland Bay, in which their hard, thick-bedded central beds are prominently shown.

In the fine exposure formed by the rocky floor of Myoch Bay their basal beds of soft green mudstones are seen following at once upon the fossiliferous calcareous beds of the Whitehouse group. Here, too, they yield an abundance of the characteristic fossil *Nematolites Grayii*, Lapw., and an occasional example of *Dicellograptus*, as at Woodland Point.

Between Shalloch Mill and the rock of Craigskelly the coast-line turns to the northward, crossing the line of strike of these beds. The central beds of the group are seen in one or two spots projecting from the sandy floor of the bay, and ranging thence into the interior of the country, where their geographical distribution will be described in subsequent paragraphs of this memoir.

It will be apparent from a study of the map (Pl. XXIV.), that we have now descrbed all the strata visible along the coast-platform between Ardwell and Shalloch, with the exception of those occurring at the extreme point of Woodland promontory, the island of Craigskelly and its neighbours, and the little point at Shalloch Forge. It

will be shown later on that these outer strata have no connexion with the Ardmillan Graptolitic series, but that they consist of massive boulder-beds and *Pentamerus*-limestones of much later geological age. They are separated from the Barren Flagstones by a gigantic strike-fault ranging from Shalloch Forge to Whitehouse Bay. The evidences of this dislocation will be given in the sequel.

In the Stinchar conglomeratic group, and the overlying Graptolitic Flagstone series, as developed along the coast-line between Kennedy's Pass and Craigskelly, we have therefore at this stage of our inquiry recognized the following succession in ascending order:—

(A) *Stinchar* or *Barr Series.*
 Ac. Benan Conglomerate of Kennedy's Pass.
 Ad. Balclatchie beds of Ardmillan Braes, 100 feet.

(B) *Graptolitic Flagstone or Ardmillan Group.*
 Ba. Ardwell Beds, at least 1000 feet.
  1'. Thin-bedded shales and mudstones, striped, carbonaceous, iron-stained, with *Diplograptus rugosus* and *Climacograptus bicornis.*
  2'. Thicker-bedded shales and flagstones, striped, ironstained, with occasional gritty seams—*Diplograptus foliaceus* and *Diplograptus pristis, Corynoides calycularis.*
 Bb. Whitehouse Beds, 300 feet.
  1. Striped flags and shales with zones of cement-stone—*Leptæna sericea* and *Dicellograptus Forchhammeri.*
  2. Variegated mudstones and calcareous shales, with *Dionide, Trinucleus, Asaphus, Agnostus, Cyclopyge, Diplograptus flaccidus, Pleurograptus linearis, Diplograptus quadrimucronatus.*
 Bc. Barren Flagstones, 500 feet.
  1. Green shales with occasional zones of flagstones—*Nematolites Grayii.*
  2. Thick-bedded green flagstones, with partings of dark green shale.

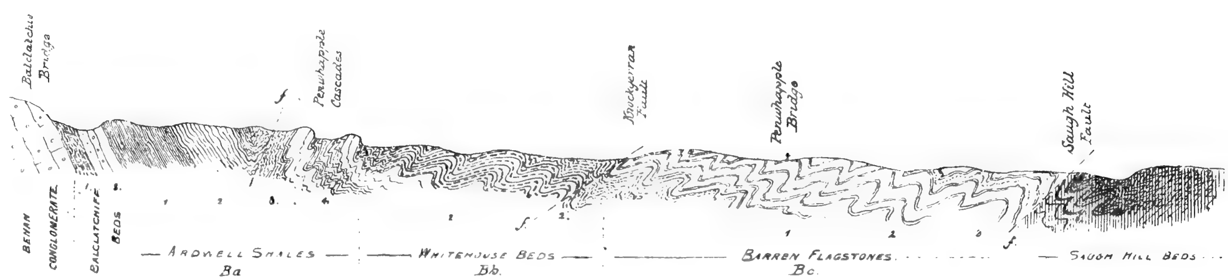
(c) *Description of the Confirmatory Section of the Graptolitic Flagstones visible in Penwhapple Glen.*

The thick series of Graptolitic and non-fossiliferous shales and flagstones which make up the Ardmillan group, attain their greatest geographical extension in the Girvan region in the moorland area to the east of Byne Hill, where they occupy a continuous tract of country from half a mile to one mile and a half in width, which stretches inland from the coast-platform of Ardwell and Shalloch (last described) to the hills of Knockgerran east of the gorge of Penwhapple.

The stream of Penwhapple, after leaving the conglomeratic area of Milljoan and Knockgerran, upon the intractable masses of which it spreads out in wide swampy flats, descends suddenly upon the softer Graptolitic series at a short distance below the bridge of Balclatchie. To the north of this point, aided by the more easily disintegrated nature of the strata over which it flows, it has excavated a profound gorge, three miles in length, and from 50 to 100 feet in depth. From end to end of this gorge a continuous and unbroken section of the rocky floor of the district is laid open to the inves-

Fig. 18.—*Confirmatory Section of the Ardmillan Rocks of Penwhapple Glen.*

S.E. N.W.



Bc. Barren Flagstones.
- (3) Thick-bedded flagstones with partings of grey shales, weathering yellow or buff in tint.—*Diplograptus truncatus* &c.
- (2) Thick-bedded grey flagstones with occasional partings of grey or green shales.
- (1) Alternations of dark grey flags and thick bands of green mudstone and shales.—*Nematolites Grayii.*

Bb. Whitehouse Beds.
- (2) Soft green and purple mudstones with occasional calcareous ribs.—*Dictyonema, Asaphus, Leptæna,* &c.
- (1) Soft banded shales and mudstones with frequent bands of cement-stone.—*Diplograptus quadrimucronatus, D. truncatus, Climacograptus tubuliferus, Leptograptus flaccidus,* &c.

Ba. Ardwell Shales.
- 4. Cascade zone of shales, mudstones with calcareous bands, thick-bedded grey grits and conglomerates.—*Dicellograptus Forchhammeri, Climacograptus caudatus,* &c.
- 3. Thin-bedded rusty shales with *Dicellograptus.*
- 2. Zone of hard thin-bedded grey flags.
- 1. Knockgerran zone of dark iron-stained shales and mudstones.—*Climacograptus cælatus, Diplograptus rugosus,* &c.

(Ad.) Balclatchie Beds.
- 2. Ashy grits and fossiliferous conglomerate.
- 1. Calcareous nodular and fossiliferous mudstones.

(Ac.) Benan Conglomerate.

ff. Faults.

tigator (fig. 18); and the evidence it affords him of the arrangement of the component strata, and of the numerous folds and dislocations which have affected them, is invaluable.

(1) Ba. *Ardwell Flags and Shales.*—For the upper two miles of its course the glen has been excavated in the flaggy rocks of the Ardmillan group. We have here therefore an excellent opportunity of testing the accuracy of our interpretation of the sequence of these strata, as deduced from their exhibition along the shore-line of Shalloch and Ardwell.

The section of the Benan Conglomerate and the succeeding Balclatchie Beds, as displayed at the commencement of the Penwhapple gorge to the north-west, has been already described (p. 249 *et seq.*).

Lying immediately upon the ashy grits of the upper zone of the Balclatchie Beds, we find the basal strata (Ba 1 of fig. 18) of the Graptolitic series. They consist of masses of dark shales and thin-bedded flagstones. The shales are more or less carbonaceous, weather throughout to a rusty-iron colour, and are clearly identical in all essentials with the lower Ardwell beds that lie upon the conglomerate of Kennedy's Pass. Beds of the same general character extend down the glen, and are magnificently displayed in its rocky floor and steep cliffs, for a distance of about a quarter of a mile, until we reach the first of a series of massive green and more or less pebbly grits, over which the waters of the burn plunge in two fine cascades.

If the dips are to be relied upon, the first group of Ardwell strata between the Balclatchie Beds and the cascades are generally arranged in a broad synclinal form. Several distinct subdivisions are recognizable as at Ardwell. The lower division (Ba^1 of fig. 18) consists of thin-bedded, striped, iron-stained shales, containing many Graptolites in certain zones. The commonest forms are:—

Diplograptus foliaceus, *Murch.*	Climacograptus cælatus, *Lapw.*
—— rugosus, *Emm.*	Corynoides calycularis, *Nich.*
Climacograptus Scharenbergi, *Lapw.*	Dicellograptus moffatense ? *Carr*

Here, however, the shales contain several bands of *cement-stone*, which yield a few Brachiopoda. Nodules of calcareous matter, too, are frequent. These contain some fine examples of Orthoceratites, an occasional shell, and fragments of sponge-spicules.

From these beds have been procured at various times by former investigators, by Mrs. Gray, by Mr. M'Fie of the neighbouring estate of Knockgerran, or by myself, the following characteristic forms:—

Orthoceras angulatum, *Wahl.*	Orthoceras politum, *M'Coy.*
—— calamiteum, *Münst.*	Hyalonema girvanense, *Nich.*

This basal (or Knockgerran) zone is overlain in the central parts of the exposure by a more flaggy series (Ba 2), answering to the more typical beds of the coast-section. Its beds consist of striped flags from 2 to 4 inches in thickness, relieved by occasional shale seams and a few insignificant bands of dark grey grit. Above follows a third subdvision (Ba 3) composed of ironstained shales, similar to

those of the basal zone. Its beds are much distorted and shattered; but Graptolites occur in the carbonaceous seams, chiefly—

Dicellograptus Morrisi, *Hopk.*	Climacograptus bicornis, *Hall.*
Diplograptus rugosus, *Emm.*	

Cascade-Beds (Ba 4).—At each of the two fine waterfalls above mentioned a mass of coarse green grits makes its appearance. In mineralogical aspect they are almost identical with those at the summit of the Balclatchie zone of the Benan-conglomeratic series, as displayed in the Doon Hill, Daldowie, and elsewhere. They occasionally become conglomeratic, being filled with zones and layers of small boulders of greywacke and quartz. They include between them a series of dark shales and mudstones, striped with lines of carbonaceous matter, and containing frequent bands and nodules of cement-stone. These calcareous seams, however, unlike those of the succeeding Whitehouse Beds, afford no examples of Brachiopoda, but are crowded with Graptolites in excellent preservation. In mineralogical aspect the beds remind us of those found on both margins of Ardwell Bay, at the summit of the Ardwell group; and their identity is placed beyond question by the fact that they contain all the peculiar fossils of that especial locality, viz.:—

Dicellograptus Forchhammeri, *Gein.*	Diplograptus foliaceus, *Murch.*
Lasiograptus margaritatus, *Lapw.*	Climacograptus caudatus, *Lapw.*
Diplograptus pristis, *His.*	Dicranograptus ramosus, *Hall.*

(2) Bb. *Whitehouse Beds.*—Immediately we examine the floor of the glen below the second waterfall, it becomes evident that we have overpassed the limits of the Ardwell beds, and have reached the more varied overlying strata of Whitehouse Bay. The beds are faulted and folded even more intensely than upon our coast-section, the same strata coming to the surface again and again as we descend the course of the stream. From the lower cascade to the point in the glen where we meet with the terminal calcareous and variegated beds of this division, the distance, as measured upon these strata in the gorge itself, cannot be less than half a mile; yet, owing to the many repetitions and faults that have affected the strata, it is doubtful if their collective thickness is more than equal to that estimated in our typical locality upon the shore-line. All the beds have a southward inclination, as if passing below the Cascade-grits; but when the several recognizable zones are studied in detail, it becomes clearly evident that they are arranged in series of zigzag forms upon the ground, demonstrative of the presence of numerous broken and inverted arches, the axes of which cross the stream-course at a very acute angle. Thus, in spite of the prevalent southward dip, it may be regarded as certain that there is a general ascending sequence as we descend the stream. This conclusion is supported not only by the facts obtainable in the neighbouring areas, but by the circumstance that the variegated seams of the Upper Whitehouse Beds are found at the north end of the section, in a position answering to their place in the sequence of the corresponding strata upon the shore-line.

As at Whitehouse, the majority of the Lower Whitehouse beds consist of dark grey shales striped with dark lines of carbonaceous matter, and containing at intervals seams, flags, and ribs of hard calcareous grit or "cement-stone," with fragmentary Brachiopoda. Here, however, the shales are much looser and softer in texture, and are altogether much more fossiliferous than in the shore-section. They have, indeed, rather the character of the soft muddy beds of this group as developed in the lower part of the Byne-Hill Burn; and the fossils they contain place it beyond question that many of them actually appertain to that special zone. The majority of the shales weather to a rusty-red colour. They yield the following Byne-Hill-Burn Graptolithina in some profusion, and in a most perfect state of preservation:—

Pleurograptus linearis, *Carr.*	Diplograptus foliaceus, *Murch.*
Leptograptus flaccidus, *Hall.*	—— truncatus, *Lapw.*
Climacograptus tubuliferus, *Lapw.*	Corynoides calycularis, *Nich.*
Diplograptus quadrimucronatus, *Hall.*	

Upper Whitehouse Beds (Bb 2).—In the place where we should expect to find the ribbed mudstones that lead up into the purple shales of the upper zones of the Whitehouse Beds we find instead a thickness of nearly 100 feet of soft dark bluish-green mudstones devoid of ribs. They are well seen in the bed and bounding cliffs of the burn, forming a most distinctive band in the rocky succession. They break up under the hammer first into beds of 3 or 4 inches thickness, and afterwards into irregular-sided blocks, with a clearly marked conchoidal fracture. As a rule, no fossils whatever seem to be obtainable from these beds, though they look very promising for the palæontologist.

They are followed immediately by a very meagre representative of the purple and green mudstone group, of which only a few feet are visible in the bed of the stream; but these are clearly intercalated, as upon the shore-line, between the grey mudstones last referred to and the Barren Flagstones, which next form the cliffs for a long distance down the stream. These variegated mudstones, though wanting in their proper thickness, probably owing to the presence of faults, show us, nevertheless, a satisfactory quantity of their associated calcareous zones, which are here much harder and more flag-like than upon the shore.

Graptolites are difficult to procure; a few fragments of *Dictyonema*, *Ganocladium*, and *Climacograptus* are all that I have been able to identify from them. But Brachiopoda are abundant in the thick-bedded "cement-stones;" examples of *Leptæna tenuistriata*, *Orthis biforata*, *Orthis calligramma* and their usual associates are by no means rare.

(3) Bc. *Shalloch or Barren Flagstones.*—The seam of purple and green shales of the Upper Whitehouse-beds, last described, has a thickness of about 30 feet. It is succeeded immediately by a great mass of Barren Flagstones, which extend down the course of the stream for the next three quarters of a mile. As in our much more

restricted coast-section, the first division of this group consists (Bc 1) mainly of green mudstones, with distant ribs of flagstone. This division is most conspicuous in the floor of the glen between the line of the variegated mudstones and the foot of Laigh Assel Burn. The stream has worn away the soft shaly mudstones into deep hollows, between which rise the hard and conspicuous intercalary ribs. In one or two spots these mudstones are crowded with their characteristic organism, *Nematolites Grayii*, Lapw., of the corresponding beds of Shalloch Mill.

Continuing our progress down the stream, beyond the terminal strata of this essentially shaly division we encounter bed after bed of rock of the same general type, but in which the sandstone and flaggy ribs become rapidly more numerous and of greater thickness (Bc 2). These all dip invariably to the southward, as if passing below the Whitehouse Beds of the higher parts of the burn; but the rapid variation in strike and dip, and the frequent faults, show that it is impossible to suppose that we have here a true ascending section, but that, as in the former case, we are dealing with a rapid succession of inverted folds. Excellent sections of the beds are seen until we reach the termination of the group, a quarter of a mile to the north of Penwhapple bridge, where it is abruptly faulted against a series of black Graptolitic shales of the much newer *Pentamerus*-group of Saugh Hill.

Some hard grey gritty flags, with interbedded subcalcareous shales, visible in the broken sections near the northern termination of these beds, are different from any of the strata of this group recognizable upon the shore, and are probably higher in the series than any strata there displayed. They are, however, most distinctly to be placed in the same subformation of the Barren Flagstones, with which they agree in all essential particulars, and of which they undoubtedly form an integral portion in this locality, and a few others yet to be described.

They contain a few fragmentary Graptolites in the greyish brown shales seen in the land-slips near the great fault. The only form clearly recognizable is *Diplograptus truncatus*, Lapw.

Thus in this section in Penwhapple Glen we recognize, lying between the Benan Conglomerate and the Great Fault, a series of strata whose members are identical in geographical succession, in mineralogical characters, and in fossils, with those developed in our typical area of Ardmillan. This sequence, though repeatedly broken by numerous and important dislocations, bears evidence of having been originally identical with that of Ardmillan in every particular, many of the most characteristic petrological zones there exhibited being developed here in positions precisely correspondent. The apparent dip of the beds through a great part of the section is, it is true, different from that seen upon the shore-line; but, as we have shown, it may be regarded as certain that these inharmoniously-dipping beds are actually arranged in rapid and inverted folds.

It will next be shown that a corresponding arrangement obtains universally among the remaining exposures in the Girvan district.

(d) *Additional Exposures of the Graptolitic Flagstones south of the Girvan Valley.*

1. *Area of Pinmore and Letterpin.*—The long strip of Ardmillan shales which stretches from Daldowie south-eastward to the valley of the Lendal, affords us by far the most satisfactory exposures of the Ardwell Shales considered in their fossiliferous character. The line of railway running from Girvan to Stranraer traverses the district almost at right angles to the strike of the beds; and its cuttings afford a magnificent and practically unbroken section from the bottom to the top of the series as there exhibited. The lowest strata exposed are certain green concretionary mudstones which are seen in the roadway underneath the great viaduct of Kinclaer. These probably belong to the transitional Balclatchie group, the main mass of whose beds are cut out by a small fault ranging along the strike of the rocks between that exposure and the great masses of Benan Conglomerate visible on the hills to the southward and in the stream-bed of the River Assel a few yards below.

Above these green mudstones follows a great thickness of very dark greyish-blue shales, beautifully shown in the railway-cutting, dipping steadily to the north-eastward at an angle of about 30°. They are fully as indurated as their counterparts in the lower portion of our typical section of Ardwell shore; but, in place of being practically barren, many of their laminæ are covered with easily identified examples of:—

Dicranograptus Nicholsoni, *Hopk.*
Dicellograptus Forchhammeri, *Gerv.*
Diplograptus foliaceus, *Murch.*
—— rugosus, *Emmons.*
Cryptograptus tricornis, *Carr.*
Climacograptus caudatus, *Lapw.*
—— bicornis, *His.*
Leptograptus flaccidus, var. *Hall.*
Corynoides calycularis, *Nich.*
&c.

Numerous scattered exposures in quarries and in the railway-cuttings enable us to complete the section as far as Letterpin fault. The beds remain essentially the same throughout. As we near the railway-station seams of cement-stone, grits with angular quartz-pebbles, and patches of coarse brown and more or less calcareous flagstones make their appearance at irregular intervals. Some of these probably belong to the underlying Balclatchie Beds. They contain many specimens of Brachiopoda, usually in a fragmentary but easily recognizable condition.

These Balclatchie and Ardmillan strata, a little further to the west, bear evidence of being arranged more or less in a synclinal form. The coarse yellow gritstones with fossils, seen in the numerous quarries around Mickle Letterpin and Chapelcroft, are probably identical with the Balclatchie zones of the railway-cutting, and are well exposed in many quarries and small natural sections over the fields in the neighbourhood of the Letterpin fault.

In these scattered exposures, more especially in one small quarry about one third of a mile north of Mickle Letterpin, certain grey and striped shales represent the transitional band at the base of the Ardwell group. From these I have procured, among others :—

Dicranograptus spinifer, *Lapw.*	Climacograptus bicornis, *Hall.*
Dicellograptus, sp.	—— Scharenbergi, *Lapw.*
Leptograptus flaccidus, var. β.	Orthis Actoniæ.
Diplograptus foliaceus, *Murch.*	Leptæna tenuistriata.
Cryptograptus tricornis, *Carr.*	

Similar beds may be followed at intervals over the entire area of this district as marked upon the map (Pl. XXIV.). In the hollows between we see the typical dark blue or grey and more or less striped shales of Ardwell, weathering to their typical rusty-brown colour—here hardened and barren, there softer and affording a few Graptolites, always of the species of the shore. Along the line of the southern conglomerate many of the beds are inverted and highly indurated. The presence of the soft yellow sandy conglomerates of the Balclatchie Beds along the line of the fault to the north renders the west boundary of the beds in that direction more obscure.

The recurrence of similar mineralogical zones of strata in the series as developed in this extended area, though the group, as a whole, apparently dips steadily to the northward, makes it certain that the numerous inverted folds and accompanying faults, apparent on the flanks of Daldowie Hill, are prolonged into the Pinmore area; and to these are due the monotonous character and great apparent thickness of the beds.

2. *Exposures East and West of Penwhapple Glen*—The section we have described in Penwhapple Glen is typical of the structure of the entire area occupied by the Ardmillan group between the Benan Conglomerate and the great fault of Saugh Hill, south of a straight line ranging from the Dow Hill across the region into the faulted area of Dalamford, on the terrace of Straiton and Garleffin. This entire district is floored with repetitions of the various subordinate members of the Ardwell Beds. The varying lines of strike are all clearly dependent upon the general outline of the mass of Benan Conglomerate, which everywhere underlies these rocks around the broad curve forming the southern and eastern limits of the area from Balclatchie to Piedmont. The strata are clearly more or less folded and faulted throughout; but the general similarity of the beds from bottom to top of the series, and the scanty exposures within the area, do not allow us to offer more than a general idea of the arrangement of the strata.

The finest sections to the southward are seen around the Barbae Hill near Tramitchell, where the fossiliferous Barbae Grit is seen to be surmounted by soft dark shales of the Lower Ardwell beds, containing a few shells and Graptolites in the intercalated cement-stones and conglomerate bands, and passing upwards into a great thickness of hard flaggy gritstones, separated by the usual rusty and striped carbonaceous shales. These shales and overlying flags sweep in a continuous curve, $2\frac{1}{2}$ miles in length, from Tra-

mitchell through Barbac Hill into the heights of Trowier, parallel to the northern boundary of the Benan Conglomerate. The higher zones of these gritty beds become more sandy, and contain seams of small quartz pebbles here and there; and they are, I suspect, the equivalents of the Cascade-grits of the Penwhapple section. In the fields N.W. of Barbae they contain fragments of Encrinites and a few Brachiopods. The underlying softer shales are best seen on both sides of the roadway west of Barbae, and in the streams near Laggan, where they contain a few Graptolites.

In the great sheet of Ardwell flagstones displayed in the heights of Tralodden, Trowier, and Balgavarie, the strata are so broken and folded that no extended sections are visible. Nevertheless there is a sufficiency of evidence to show that the Benan Conglomerate rises again and again almost to the surface, while the various zones of the Ardmillan series are often recognizable in place upon the ground.

Ba, *Ardwell Beds.*—Excellent exposures of the Knockgerran or lower zones of the Ardwell Beds are afforded by the two small streams which unite at the farm of Tralodden. The beds show their usual striped appearance, contain the normal cement-stones, and are locally crowded with

Diplograptus pristis, *His.*	Climacograptus caudatus, *His.*
—— foliaceus, *Murch.*	Corynoides calycularis, *Nich.*

A mass of similar beds is cut through by the lower reaches of the Piedmont Burn, near Glendoune. This is included between two divergent branches of the great bounding fault of the Girvan plateau. This fault, as will be evident from a study of the map, splits into two branches north of the summit of Saugh Hill; and in the included angle between them we find examples of the higher parts of the conglomerate or cascade group, together with some of the lower divisions of the Ardmillan series.

Fossils occur both on the flanks of Saugh Hill and in the depths of Piedmont Glen. At the latter locality I have collected

Diplograptus pristis, *His.*	Corynoides calycularis, *Nich.*
—— foliaceus, *Murch.*	

Diplograptus foliaceus and *Corynoides calycularis* occur also in the quarries on Fauldribban Hill.

In Piedmont Glen the middle zones of the Ardwell Shales are crowded with Graptolites at the foot of the small burn which descends from Laggan Loch. Here are found in excellent preservtion :—

Diplograptus foliaceus, *Murch.*	Climacograptus caudatus, *Lapw.*
—— pristis, *His.*	Corynoides calycularis, *Nich.*

At the foot of the glen itself occasional examples of *Lasiograptus margaritatus*, Lapw., and *Diplograptus foliaceus*, Murch., are met with in the contorted beds. They occur also in corresponding strata upon the low mound of Shalloch Hill.

A similar faulted patch of the Knockgerran zone of the Ardwell Beds occurs near the farm of Pinmacher, and is cut through by the

railway-line from Girvan to Stranraer. Excellent sections are visible in the railway itself near the tunnel and in several quarries near the farmsteading of Knockrochie. Graptolites are abundant in a few spots, especially *Diplograptus pristis*, His., and a form of *Climacograptus.*

The highest zone of the Ardwell Beds—the peculiar *Cascade Grits and Shales* of Penwhapple Glen, is recognizable at several localities. From the Cascades themselves its strata are prolonged to the eastward in a continuous band of small cliffs, which form a prominent feature upon the grassy slopes of Balgavarie Hill. In the stream which descends the slopes of the hill they afford a visibly ascending section, and yield their usual Graptolites in a state of excellent preservation. Here occur

Dicranograptus Nicholsoni, *Hopk.*	Climacograptus caudatus, *Lapw.*
—— ramosus, *Hall.*	Diplograptus foliaceus, *Murch.*
Dicellograptus Forchhammeri, *Gein.*	Climacograptus bicornis, *Hall.*

The same zone is seen also upon the heights of Trowier Hill in the same stratigraphical position, and yielding precisely the same fossils.

A most interesting patch of the same band is found at the base of the north-western flank of Saugh Hill (see fig. 25, p. 299). Here it is caught up between two branches of the great Bargany dislocation; but its strata retain their normal characteristics, and afford the usual fossils, namely:—

Dicranograptus ramosus.	Dicellograptus Forchhammeri.
Climacograptus bicornis.	Diplograptus rugosus.

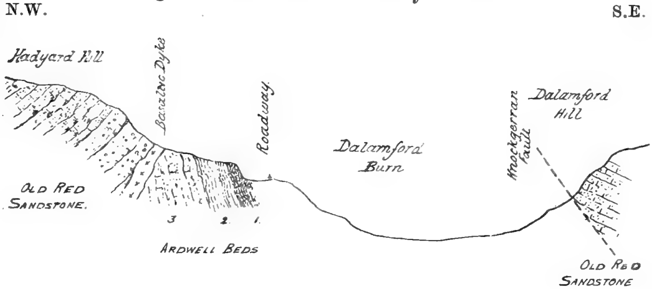
But the most remarkable exhibition of the beds of this zone is the section afforded by the narrow valley of Dalamford, about two miles east of the Penwhapple Glen. Here a strip of Lower Palæozoic strata several miles in length, but only about 100 yards in width, is bounded on both sides by rocks of Old Red Sandstone (see map, Pl. XXIV.). Along the roadway near Dalamford the visible Lower Palæozoic rocks are those of the Cascade-zone, and the transverse section of the valley is that given in the following section (fig. 19).

This narrow band owes its existence to the presence of the great Knockgerran fault, which is prolonged into this locality from the valley of the Penwhapple. The strata exposed along its course are not, however, confined to the Cascade-zone. The Stinchar Limestone is brought up in a shattered condition near the steading of Pentbeath, and is said to occur also in the south-eastern branches of Penwhapple Burn.

Bb, *The Whitehouse Beds.*—Only a very limited number of exposures of the beds of this group have been met with in this area. Beds unequivocally belonging to the Lower or Cement-stone-bearing division occur at the head of Piedmont Glen, where they follow in their proper position upon the grits of the Cascade-zone. In their shattered beds, as laid open in the stream-course, the usual fossils are procurable, chiefly:—

Diplograptus quadrimucronatus, *Hall.*	Dicellograptus Morrisi, *Hopk.*
—— truncatus, *Lapw.*	Leptograptus flaccidus, *Hall, &c.*

Fig. 19.—*Section in Dalamford Glen.*



Old Red Sandstone:—

Coarse red conglomerates and red and yellow flagstones.

Ardwell beds, Cascade-zone.

3. Calcareous grits, with partings of green and grey shales.
2. Green nodular sandstones, non-fossiliferous.
1. Black carbonaceous and ferruginous shales, with occasional hard arenaceous ribs—*Lingula, Dicellograptus Forchhammeri, Diplograptus rugosus, D. foliaceus, Climacograptus caudatus*, &c.

Strata belonging to the higher or Upper division have been detected only at a single locality between the two exposures of Myoch Bay and Penwhapple Glen, already described, namely, in the central parts of the gully formed by the north-east fork of Piedmont Burn. Here the purple and green mudstones of the Upper Whitehouse variegated beds form the bed and banks of the stream-course for some little distance, in their natural geological place between the Ardwell beds of Trowier Hill and the *Nematolites*-bearing flagstones of Doune Hill. They are much shattered, and have afforded no recognizable fossils. The boundaries of this zone, as given upon Plates XXIV. and XXV., west of Penwhapple Glen, are almost purely inferential, as hardly any sections are visible upon the grouud.

B. *Barren Flagstones.*—The succeeding Barren-flagstone beds form a broad zone, about four miles in length and half a mile in width, which ranges from the summit of Doune Hill across the glen of Penwhapple into the moorland area north-west of Knockgerran. The central section of this zone in Penwhapple Glen, already described, is typical of the general arrangement of these strata from end to end of the band. The thin-bedded zones near the base of the group are well seen on the southern and south-western slopes of Doune Hill. The higher and flaggy beds are laid open at several spots upon the heights between Saugh Hill and Penwhapple; and by their disposition upon the ground enable us to mark out with some approach to certainty the line of the fault which bounds the band to the northward. In Saugh-Hill Burn itself they afford specimens of the characteristic fossil *Nematolites Grayii*; and in some quarries about a mile to the eastward, they yield examples of *Diplograptus pristis* and *D. truncatus*. There are many exposures of the same beds south and east of the farmstead of Littlelane; but no fossils have been obtained from them.

A patch of unfossiliferous strata, probably referable to the lower division of the Barren-flagstone beds occurs to the south-west of Brae Hill. It is cut off from all the neighbouring strata by faults of great magnitude; and it is therefore referred to this division with some doubt. Good exposures of its beds are seen in Cuddystone Glen and on the west side of Brae Hill. The strata are green and grey shales, with occasional beds and bands of flagstone, all totally barren of recognizable fossils, and altogether very similar to the highest zone of the Barren-flagstone group.

This completes our survey of the distribution of the Graptolitic-flagstone series *south* of the Girvan Valley. The remaining strata are very different in their characters, petrological and palæontological, from those we have studied hitherto; and their description is most conveniently deferred until we have made out the arrangement of the palæozoic strata which are exposed *north* of the Girvan Valley, on the heights of Craighead and Quarrel Hill, where rocks unquestionably belonging to the Ardmillan-flagstone series are exposed in several localities, with clear relations to the overlying strata.

(C.) Description of the Strata of the Northern Inlier of Craighead and Glenshalloch.

The Lower Palæozoic strata, whose interrelationships fall next to be described, occur in the prominent heights of Craighead, Quarrel Hill, and Glenshalloch, which together constitute the beautifully wooded ridge that forms such a conspicuous object to the north of the valley of Girvan, a few miles inland from the mouth of the river. These strata form a well-marked inlier, which is bounded on all sides by more recent beds of Old Red Sandstone and Carboniferous age; and, broadly speaking, it may be said that they are arranged in a dome-like or anticlinal form. The longitudinal axis of this anticlinal is not precisely coincident with the geographical axis of the ellipsoidal area occupied by the Lower Palæozoic strata, but lies a little to the southward. In consequence of this arrangement the strata forming the southern leg of the anticlinal have a short curve and a steep dip to the south-western margin of the area, where they are suddenly cut off by the grand boundary fault of Kilkerran and Craighead. Northwards, however, the beds have a gentle inclination, the angle of dip rarely exceeding 45°, and being sometimes as low as 10° or 12°.

The axis of the main anticlinal, instead of being approximately horizontal, is archlike, being depressed in both directions as we pass along it from its central point. The long elliptical dome thus originated has been truncated by denudation; and its component beds are now shown upon the ground as a series of concentric shells or zones of strata dipping everywhere outwards off the central parts of the dome. They admit of minute and almost complete examination in several localities. The general coating of wood and turf, however, hides some of the inferior beds from sight in the eastern and southern parts of the area; but towards the north-east a long and easily

interpreted ascending succession is displayed in the heights of Quarrel Hill, Mulloch Hill, and Glenshalloch.

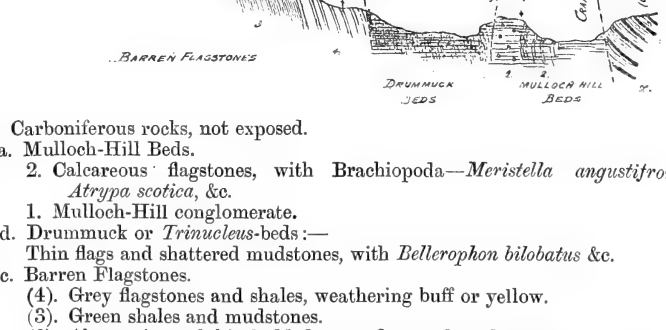
(a) *Sections of the Inner Zones of Strata of the Quarrel-Hill Anticlinal.*

(i) *Barren Flagstone-series of Farden and Quarrel Hill.*

In the centre of this dome-like area, and consequently occupying the lowest horizon in the vertical succession of its rock-formations, we find a series of barren flagstones and shales, identical, both in their petrological characters and in the few organic remains they yield, with our Barren or Shalloch Flagstones of Shalloch and Penwhapple—thus presenting, at the very commencement of our study of the rocks of this area, a clear and definite horizon of reference for the surrounding and concentric zones of strata of which this northern inlier of Lower Palæozoic rocks is composed.

These flagstones occupy an ellipsoidal area about a mile in length, ranging from the loop-fault which bounds the igneous rocks of Craighead Hill, through the wooded grounds of Balweary, into the grassy slopes of Quarrel Hill. Over much of the area they occupy they are hidden from sight by superficial deposits; but excellent sections are laid bare in the burns which descend the ridge in the direction of Craighead fault, near Kildrummie. The most satisfactory of these exposures is that seen on the banks of the small stream to the west of Quarrel Hill, where the section figured below is displayed from end to end (fig. 20).

Fig. 20.—*Section of the Barren Flagstone Beds of Quarrel Hill.*



x. Carboniferous rocks, not exposed.
Ca. Mulloch-Hill Beds.
   2. Calcareous flagstones, with Brachiopoda—*Meristella angustifrons*, *Atrypa scotica*, &c.
   1. Mulloch-Hill conglomerate.
Bd. Drummuck or *Trinucleus*-beds:—
   Thin flags and shattered mudstones, with *Bellerophon bilobatus* &c.
Bc. Barren Flagstones.
   (4). Grey flagstones and shales, weathering buff or yellow.
   (3). Green shales and mudstones.
   (2). Alternations of thin-bedded green flags and mudstones.
   (1). Thin-bedded flaggy beds, with partings of green and grey mudstones—*Nematolites Grayii* and *Diplograptus truncatus*.
ff. Faults.

The lowest beds of the Flagstone series visible at this locality are seen at the head of the little burn, circling round the declining axis of the main anticlinal arch, and gradually acquiring a steep southward inclination as we descend the course of the stream. The oldest beds are greyish-green flagstones, from two to four inches in thickness, separated by the usual pale bluish-green seams of shaly sandstone, characteristic of the higher parts of the "*Barren Flagstones*" as seen near the Saugh-Hill fault in the gorge of Penwhapple. They contain their peculiar fossil, *Nematolites Grayii*, Lapw., in some abundance, together with a few scattered examples of the equally characteristic Graptolite *Diplograptus truncatus*, Lapw.

Lower down the stream the flagstones and shales differentiate themselves in wider bands, and the strata put on an appearance identical with that of the most typical Barren Flagstones of Penwhapple, showing the same regular alternation of a foot of hard grey grit with two or four feet of greenish flaky shales. Below the little wood the beds become steeper, and, as will be seen from the map (Pl. XXV. 4) and sections, begin to be much broken up by faults. Their highest beds as seen here are pale flagstones, with a light-blue interior, associated with similarly tinted mudstones, both weathering to the dull orange-buff colour affected by the beds of this formation whereever they have been long exposed to the action of the atmosphere.

A confirmatory section is visible in Farden Burn, about three fourths of a mile to the south-westward of Quarrel Hill. The oldest beds, ranging along the anticlinal line, occur in the banks of the stream at the back of the farmsteading of Farden, dipping in opposite directions at a small angle. As we descend the stream to the south the angle of inclination rapidly increases; and between the steading and the Craighead fault we pass over a fairly continuous section of these beds, the majority of which are identical with the pale and buff-coloured flags and shales that terminate the exposure in Quarrel-Hill Burn, while they are similarly destitute of organic remains of any kind.

These Barren Flagstones are seen upon the opposite side of the anticlinal line in two localities only. One of these occurs in an old quarry a quarter of a mile to the west of Blair Farm, the other on the road-side at the farm-house itself. In both localities we find the barren buff-weathering shale and flagstones of the highest zone of the series, as usual, perfectly destitute of fossils.

The numerous faults and folds of the district do not allow an exact calculation of the vertical thickness of the portion of the Shalloch or Barren-flagstone group as here exposed. It may be roughly estimated at about 300 feet. The buff-tinted terminal band of flagstones and shales cannot be less than 100 feet in total thickness. This is apparently wanting in the Penwhapple exposure of these beds, and its thickness falls to be added to our estimate of the vertical extent of the Barren Flagstones of that area. This would give a collective thickness of about 800 feet to the entire formation of the Barren Flagstones as seen in the Girvan region.

(ii.) *Trinucleus-Mudstones of Drummuck.*

Round three fourths of the superficies of the anticlinal dome of Quarrel Hill the Barren Flagstones are succeeded by the highly fossiliferous group of dark mudstones which I term the Drummuck Beds. In mineral aspect and in fossils they remind us strongly of some of the zones of the Whitehouse shales (Bb) that immediately underlie the Barren-flagstone series; but they contain none of the brilliantly coloured mudstones of that group, nor any of the beautifully striped and banded shales which it possesses in common with the older Ardwell group. The physical relations of the Barren Flags and these overlying *Trinucleus*-mudstones are best displayed in the flanks of Quarrel Hill; but the finest and most prolific sections of the latter group are shown to the north, along the course of the Lady Burn, and in the neighbourhood of the farm of Drummuck, which gives its name to the subformation.

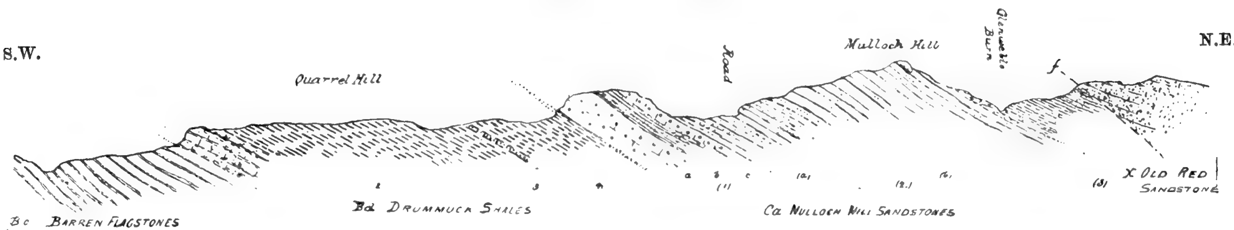
The superposition of these fossiliferous mudstones to the Barren-flagstone group will at once be understood from the following section (fig. 21, p. 618), which is carried in an easterly direction along the anticlinal axis from Balweary Wood to Mulloch Hill. Indeed the disposition of the several zones of strata which here cross over the anticlinal, as developed in the mapping of the area, make this so clear and unequivocal that no further proof of their relationship is necessary in this place.

1. *Quarrel Hill.*—The lowest strata I assign to the Drummuck Beds are a group of thick-bedded flagstones, filled with pebbles of quartz, and separated by seams of grey and green shales, both rocks containing a notable proportion of carbonate of lime. They are exposed in a steep escarpment at the summit of Quarrel Hill, dipping off the Barren Flagstones and plunging below the area occupied by the main mass of the Drummuck Beds. From this point, as will be seen from the map (Pl. XXV. 4), they may be followed foot by foot, occupying the same stratigraphical place in the succession, through the converging dislocations of Quarrel Hill, circling round parallel with the overlying and underlying zones, till they are finally cut out by a branch of the Craighead fault to the south-west of the old ruin of Auldthorns.

These pebbly flagstones have a collective thickness of about 50 or 60 feet, and abound in casts of fossils of the same general facies as those characteristic of the overlying mudstones. The commonest forms are *Leptæna sericea* and *Strophomena.*

The finer strata which succeed to these basal flagstones are well displayed in the numerous stream-courses that descend the eastern flanks of Quarrel Hill. Their upper boundary is strikingly defined by a mass of purple conglomerate, which forms the base of an overlying group, and ranges through the faulted areas strictly parallel with the basal flagstones last noticed. In the area thus limited, we find a great thickness of mudstones and shales of a greyish-blue colour, very rarely interrupted by thin seams of greenish-grey flagstone or greywacke. The lowest beds are hard shales, of tough texture, weathering down into conchoidal flakes. Higher up

Fig. 21.—*Section through the Ardmillan and Newlands Beds of Mulloch Hill &c.*



x. Coarse conglomerates and yellow grits of *Upper Old Red Sandstone.*

C. Newlands Series.

Ca. Mulloch-Hill Beds.
- 3. *Ptilograptus*-shales—yellow shales and mudstones, with *Ptilograptus* &c.
- 2. Mulloch-Hill sandstones (Brachiopod Sandstones).
  - (*b*) Rough-Neuk beds. Thick-bedded soft grey and green sandstones, with partings of calcareous shales—*Orthis mullochensis* &c.
  - (*a*) High-Mains beds. *Meristella angustifrons, Strophomena expansa, Atrypa scotica,* &c.
- 1. Mulloch-Hill conglomerate.
  - (*c*) Upper conglomerate.
  - (*b*) Grey tilestones, with Brachiopods.
  - (*a*) Lower conglomerate.

B. Ardmillan Series.

Bd. Drummuck or *Trinucleus*-mudstones.
- 4. Thraive beds, with *Ampyx, Dionide, Trinucleus,* and *Dicellograptus anceps.*
- 3. Starfish-bed. Grit band, with *Palæaster Wyville-Thomsoni* &c.
- 2. Quarrel-Hill mudstones and flags, with *Bellerophon acutus* &c.
- 1. Quarrel-Hill flags and conglomerates, with *Leptæna sericea* &c.

Bc. Barren Flagstones of Quarrel Hill and Balweary, with *Diplograptus truncatus* &c.

they deserve rather the title of bedded mudstones, occurring in distinct bands at least a foot in thickness. The terminal beds are soft sandy mudstones, weathering down into irregularly rounded fragments, coated exteriorly with oxide of iron.

Fossils are tolerably abundant throughout, more especially in the central beds, which afford, among others:—

Trinucleus seticornis, *His.*	Bellerophon bilobatus, *Sow.*
Ampyx rostratus, *Sars.*	—— perturbatus, *Sow.*
Illænus, sp.	Orthis calligramma, *Dalm.*
Dionide, sp.	—— elegantula, *Dalm.*
Calymene Blumenbachii, *Brongn.*	Leptæna sericea, *Sow.*

On the north-east side of Quarrel Hill no exposures are apparent; but a short distance to the westward the stream of the Lady Burn has excavated a most interesting and instructive series of sections more than a mile in length through the higher zones of the group.

2. *Lady Burn.*—Near the head of the Lady Burn we find the purple Mulloch-Hill conglomerate crossing the little stream-valley almost at right angles to the course of the burn. Over this intractable rock the waters of the stream leap in a small waterfall, at the base of which the highest known strata of the *Trinucleus*- or Drummuck-beds are seen, dipping steadily and conformably underneath the conglomerate at an angle of about 40°. They are soft, blue mudstones, homogeneous, thick-bedded, and more or less concretionary in structure, breaking up under the hammer into irregular and crumbling fragments. Exteriorly they are stained with rusty oxide of iron; interiorly they are pierced by frequent inosculating worm-burrows, stained of a dingy red. Fossils are very rare; only an occasional Brachiopod is discernible.

At their base, however, they contain a fossiliferous band, the abundant organic remains of which fully compensate for the barren nature of the beds above. Fragments of this fossiliferous band are exposed in an old quarry opened for procuring materials for the neighbouring stone walls, in which an occasional slab from the fossil seam may even yet be detected. The bed itself is a hard greenish-grey sandstone, a few inches in thickness, and highly calcareous. It is almost made up of fossil remains, many being in an excellent state of preservation.

Among others, I have collected from this bed:—

Palæaster Wyville-Thomsoni, *R. Eth.*	Leptæna sericea, *Sow.*
Trinucleus Bucklandi, *Barr.*	Orthis calligramma, *Dalm.*
Illænus Bowmanni, *Salt.*	Conularia Sowerbyii, *Defr.*
Staurocephalus globiceps, *Portl.*	Strophomena grandis, *Sow.*
Calymene Blumenbachii, *Brongn.*	

together with forms of corals and Polyzoa of undeterminable specific characters.

The shales immediately below the Starfish-bed range down the remainder of the stream-course to the farm of Drummuck, and are shown in an abundance of natural sections. They have been frequently examined by Mrs. Gray and the officers of the Geological Survey, and have long been noted for the abundance and beauty of

the Trilobites they have afforded. They consist of pale-blue or greyish-green mudstones of the same general type as these at the summit of the subgroup; but they are harder, and often contain a a notable proportion of sandy material.

In the section shown upon the burn-side opposite the farmsteading of South Thraive Mr. and Mrs. Gray have collected:—

Trinucleus seticornis, *His.*	Dionide Lapworthi, *R. Eth. jun.*
Ampyx rostratus, *Sars.*	Bellerophon bilobatus, *Sow.*
Solenocaris solenoides, *Young.*	Dicellograptus anceps, *Nich.*

Where the succeeding plantation comes upon the stream-course similar beds are seen containing numerous fossil forms. Here I have myself distinguished:—

Diplograptus truncatus, *Lapw.*	Bellerophon bilobatus, *Sow.*
Trinucleus Bucklandi, *Barr.*	—— trilobatus, *Sow.*
Illænus Bowmanni, *Salt.*	Holopella obsoleta, *Sow.*

Midway between Thraive and Drummuck, beds a little lower in the succesion are shown. These Mrs. Gray found to be prolific in beautifully preserved specimens of

Ampyx rostratus, *Sars.*	Trinucleus seticornis, *His.*

At the farm of Drummuck itself the *Trinucleus*-beds are admirably shown in a small stream running parallel to the roadway to the south of the steading. Here fossils are not so numerous as in the former localities cited; but occasional Brachiopoda are found beautifully preserved.

The oldest strata of the Drummuck Beds seen in this locality are exhibited in a small stream crossing the roadway a quarter of a mile south of the farmhouse, and again in a small quarry near the head of Drummuck Burn itself. In both these localities we recognize the greenish thin-bedded lower shales of Quarrel Hill, and identify within them an occasional fossil.

Westward, the *Trinucleus*-strata are buried beneath recent accumulations and surface-soil; and, except in two small exposures, one at the little pond near the toll-bar at Trochraive, and another on the north-west corner of the enigmatical rock-area of Craighead Hill, nothing further is known of their extension in that direction.

This prolific subdivision of *Trinucleus*-mudstones and shales is denominated the Drummuck Beds, after the name of the farm in the neighbourhood of which its strata are most effectively displayed. The subdivision forms the highest member of the Graptolitic flagstone or Ardmillan group of our Girvan succession, being succeeded by the basal zone of a superior group of rocks, totally distinct both in lithological features and in organic remains. Before proceeding to notice these higher strata, it will be advisable to give a short summary of the several bands of rock that constitute our complete Ardmillan group as we now understand it, together with the names of the several localities where their strata are typically laid open for investigation:—

Generalized Section of the Ardmillan Series.

	feet.		
Cd. Drummuck Beds .	400	Upper Mudstones.	Lady Burn.
		Starfish-band.	Quarrel Hill.
		Lower Mudstones.	Drummuck.
		Basal Sandstones.	Auld Thorns.
Cc. Barren Flagstones	800	Upper zones.	Quarrel-Hill Burn.
		Middle zones.	Penwhapple.
		Lower zones.	Shalloch Mill.
Cb. Whitehouse Beds .	300	Variegated Mudstones.	Shalloch Mill.
		Lower Whitehouse-beds.	Penwhapple Glen.
Ca. Ardwell Beds	1200	Cascade-beds.	Penwhapple.
		Middle Flags and Shales.	Ardwell shore.
		Knockgerran Shales.	Penwhapple.

(a) *Sections of the Outer Zones of Strata of the Quarrel-hill Anticlinal.*

(i.) *The Conglomerate and Shelly Sandstones of Mulloch Hill.*

Having determined the characteristics and sequence of the inner and older zones of strata of the Quarrel-Hill anticlinal, we now proceed to examine the sections which best display the corresponding relations of the outer and therefore newer zones of the dome. It will be seen from the map (Pl. XXV. 2) that the width of the Lower Palæozoic area of Quarrel Hill is not sufficient to allow these outer zones to range round the greater part of the mound-like saddle, as do the inner and inferior beds already described, but that they merely cross over the chief ridge of the declining anticlinal one by one, in successive and parallel bands, as we pass outwards to the north-east from the natural centre of Quarrel Hill, their outer edges being abruptly truncated by the Craighead and Glenshalloch faults.

The rapid convergence of these two dislocations towards the north-east progressively restricts the area individually occupied by each succeeding zone in the ascending series, until ultimately the two faults meet in the wooded heights of Glenshalloch, and the Lower Palæozoic rocks finally disappear from sight.

The older zones of the continually ascending succession of strata present in the triangular area thus limited, are most perfectly displayed in and around the central ridge of Quarrel Hill. To the northward of this central point no dislocation interferes with the sequence, and the regularly ascending series can be studied with ease and certainty; southward a plexus of faults, branches of the great Craighead dislocation, have shattered the strata into a host of irregular fragments, each one of which, however, falls naturally into its proper place after a careful mapping of the ground.

The natural arrangement of the lower divisions of these superior zones will be evident on an inspection of the foregoing section (fig. 21, p. 618), which is drawn from the central part of the Quarrel-Hill anticlinal of Ardmillan Beds, through the simple and unbroken area of Mulloch or Kirk Hill.

(Ca1.) *Mulloch-Hill Conglomerate.*—The soft blue concretionary and highly fossiliferous *Trinucleus*-beds of the Drummuck mudstones

are succeeded abruptly by a mass of very coarse boulder-conglomerate, which forms a conspicuous scarp and ridge upon the highest points of Quarrel Hill, and ranges thence eastward and southward, round the curving anticlinal arch.

This peculiar conglomerate reminds us somewhat of the massive Benan Conglomerate of the south in the size and character of its included pebbles. These are of quartz, granite, felstone, and several varieties of igneous rock. The matrix, however, is of a dull purplish tinge, and is in truth a sandy gritstone. Its grains are usually well rounded; and when pebbles are rare the rock degenerates into a coarse sandy grit. In its aspect and composition the rock resembles the bands of conglomerate so abundant among the Old Red Sandstone rocks of Scotland, especially those of the lower division of that peculiar series. It is distinctly bedded throughout its entire thickness, which does not here exceed 75 feet, the planes of deposition being marked by seams of sandstone, lines of boulders, and zones of hard grey grit. Towards its summit it includes a thick zone of sandy flagstone, or tilestone, of a reddish grey tint, containing many casts of fossils, and indicative of the commencement of the conditions which resulted in the formation of the overlying masses of sandy flagstones of Mulloch Hill.

This conglomerate is traceable from the Craighead fault at Glenlochrie, through the faults of Quarrel Hill, into the valley of the Lady Burn, and thence in patches to the farmhouse of Drummuck, following in immediate and locally conformable succession to the Drummuck shales.

Scattered exposures of similar rock are seen to the south-west of this, as near Kippery and Woodhead and, finally, in a wide area around the mansion of Trochraive. Here coarse conglomerates occur in detached quarries and in projecting bosses in the park and cultivated fields. These certainly belong to the Mulloch-Hill band; but they are flaggier and greyer, and have hardly the same characters either in their matrix or in their included pebbles.

The fossils afforded by the Mulloch-Hill conglomerate, in the type locality of Quarrel Hill, are principally Brachiopoda of the genera *Rhynchonella*, *Orthis*, *Leptæna*, and *Strophomena*, identical in species with those we shall find to be characteristic of the overlying Mulloch-Hill sandstones, and generally distinct, considered as a group, from those that mark the immediately subjacent Drummuck mudstones.

Indeed the distinction in physical features and in fossils between the soft Drummuck mudstones, with their abundant examples of *Trinucleus*, *Asaphus*, *Dionide*, *Ampyx*, and hosts of *Bellerophon* &c., and these overlying *Brachiopod*-sandstones is most striking; and we find here the grandest palæontological break in the entire Girvan succession. None of the genera enumerated above as characteristic of the Ardmillan group have ever yet been certainly met with above the base of this conglomerate; while the most characteristic species and genera of Trilobita, Brachiopoda, and Graptolithina of the overlying beds are equally absent from the Ardmillan series.

There is no actual proof of an unconformity between the Drummuck mudstones and this conglomerate; but the change in mineralogical character from a soft laminated mudstone to massive boulder-beds and sandstones is proof of a complete modification of the physical features of the neighbouring sea-bed between the periods of deposition of these highly dissimilar sediments, and the great alteration in the aspect of the fauna, caused by the disappearance of many prominent genera and species, is sufficient proof that the intervening period was of great geological importance.

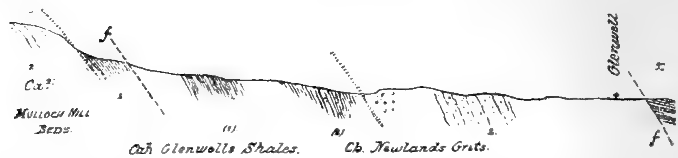
(Ca2) *Mulloch-Hill Sandstones.*—This purple conglomerate of Quarrel Hill graduates upwards into a mass of soft sandstones, at least 250 feet in thickness, which, because of their typical exhibition on the summit and flanks of Mulloch or Kirk Hill, I shall refer to as the Mulloch-Hill sandstones. They are shown in a large number of open quarries along the hill-road north-east of High Mains, and thence for some distance along the same road almost to the steading of High Newlands. A fine display of the same beds is seen in the old quarry at Rough Neuk; and they are easily studied *in situ* in the courses of the many burns that descend the flanks of Quarrel Hill. In all these localities they retain the same general facies of a thick-bedded series of sandstones separated by thin seams of sandy shales. The natural colour of the rock is a dark grey, with a slight greenish tinge; but when weathered it becomes gradually coated with an exterior tint of purple or yellowish red, which soon extends itself inwards till finally the entire rock becomes of a deep rusty or iron-shot colour.

These sandstones are soft and sectile, breaking up easily under the hammer. The more flaggy beds have usually a rough conchoidal fracture; the thicker sandstones split up much more evenly, and generally weather down into rough tilestones. The shaly alternations rarely show evidence of regular lamination, but fall away in rough and irregular flakes.

The whole mass of beds retains very much the same mineralogical character from base to summit; but in the lower zones sandstones are broadly preponderant. The highest zone of the group is actually a band of pale yellow sandstones. It passes upwards conformably into a superior group of yellow-weathering mudstones (Cb3), which, as seen on Mulloch Hill, are comparatively barren. A few Brachiopoda and species of *Ptilograptus* occur in the exposures N.E. of Kirk Hill, near the cottage of High Newlands.

The Mulloch-Hill sandstones range southeastwards from the typical localities obliquely down the slopes of High Mains into the low-lying flat of the Quarrel Burn, below the ruins of Auldthorns. They are much cut up by the many loop-faults of that complicated area, and are finally inverted and pinched out, by the converging faults of Quarrel Hill and Craighead, near Kildrummie. In the streams and exposures of the area occupied by these beds below Auldthorns the strata are crowded with fossils. They are fully as abundant as upon Mulloch Hill, and are occasionally even more completely preserved.

Fig. 22. *Section of the Strata of Glenwells Burn.*



x. Lower Carboniferous sandstones and shales (invisible along line of section)
Cb. Newlands grits and conglomerates.
  2. Yellow sandstones and flaggy grits.
  1. Coarse yellow conglomerate.
Cab. Glenwells shales.
  (2) Pale-blue flags and shales, with *Climacograptus normalis.*
  (1) Pale-blue flags and shales, non-fossiliferous.
Ca³. Mulloch-Hill beds.
  2. Yellow sandy shales, with *Leptæna*, *Orthis*, and *Strophomena.*
  1. Brachiopod-sandstones of Rough Neuk.
f.f. Faults.

In the stream which descends from the north-east slope of Kirk Hill, and flows past Rough Neuk to the cottage of Glenwells, a tolerably complete section of the strata above the shelly sandstones of Mulloch Hill is laid open (fig. 22). Near the head of the stream, a short distance below the roadway, shell-bearing beds are discovered, dipping steadily to the S.E. off the sandstone group of Rough Neuk. Lower down these beds are followed, after an interval, by a series of blue and green mudstones with intercalated harder ribs. These strata have the same general inclination as the Rough-Neuk beds; but there is some doubt whether they succeed them in conformable sequence. They continue to occupy the bed of the stream for some distance, dipping at an average angle of about 50°, the beds becoming somewhat flaggier as we ascend in the succession. They appear to be generally barren of fossils, except in certain thin seams of striped shales, which have afforded me

Climacograptus scalaris, *His.*	? Monograptus tenuis, *Portl.*
Dimorphograptus acuminatus, *Nich.*	

At this point occurs another unfortunate break in the section, and no rock-exposures are seen for a distance of between 40 and 50 yards. These pale-blue mudstones and flags of Glenwells are thus completely isolated as regards their stratigraphical position. It is by no means improbable that they are separated from the true Mulloch-Hill beds by an important branch of the Craighead dislocation, which has cut out the basal zones of the Newlands series. They agree exactly, however, in dip and strike with the underlying Mulloch-Hill beds, while mineralogically they appear to be nothing more than the upward prolongation of the *Ptilograptus*-shales at the summit of that group. The strata next visible are so distinct in their lithological characters that they must be regarded as belonging to a new subformation. Hence it will be convenient provisionally to regard the Mulloch-Hill beds as terminated by these blue mudstones, below which the descending succession is tolerably continuous down into the basal conglomerate of High Mains and Craigens.

The Mulloch-Hill beds, as thus extended, consist therefore of the following members:—

Cab. Glenwells Graptolitic Mudstones and Flags.
Ca^2. Rough-Neuk or Mulloch-Hill Sandstones.
Ca^1. Mulloch-Hill Conglomerate.

Generally speaking, it may be said that their lower beds are thicker and contain more of the purple and grey tilestones; the middle beds are alternations of thick-bedded sandy flags and sandy shales; and the upper beds show many zones of soft mudstones, pale-hearted and weathering to a golden yellow.

The entire sequence is exposed along the line of section already given (fig. 22). The thick-bedded sandstones are laid open in many spots to the left of that line in the broad hollow separating Quarrel Hill from the Mulloch Quarries. The flaggy central (or Rough-Neuk beds) occur in the quarries on the roads to the south of Mulloch, and the highest yellow pale-hearted flaggy mudstones near the house of High Newlands.

Fossils occur throughout the group, but they are comparatively rare in its highest division. In the exposures of the lower division, in the depression and roadway-quarries west of Mulloch Hill, they occur in incredible profusion, mainly, however, in the form of casts, the shell itself being weathered away and replaced by a soft ochreous matter of a beautiful orange-yellow colour. Here occur in abundance such characteristic forms as *Atrypa hemisphærica*, *Orthis reversa*, *Meristella angustifrons*, and *Rhynchonella cuneata*, together with crowd of others, of which the most remarkable is the enigmatical *Nidulites favus*, which was first described from this locality.

In some of the lower beds the shells abound to such an extent that the rock deserves rather the title of an impure limestone than that of a true sandstone. This is the case also with the succeeding central and more flaggy group, of which a deep section is shown in the old quarry of Rough Neuk, one of the most prolific spots for fossils in the Girvan district. Corals are perhaps more abundant in this part of the subgroup than in the beds below; but even here, as throughout the whole series, Brachiopoda are overwhelmingly preponderant.

(ii.) *Pentamerus-Grits and Shales of Newlands.*

It will be apparent on a study of the map and sections (Pl. XXV. 4), that these Mulloch-Hill beds form a well-marked zone, which crosses the great inlier from side to side, reposing on the Ardmillan group of the central areas, and throwing off a fresh series of beds, which occur only in the north-easterly angle of the inlier in the neighbourhood of the farmstead of Newlands and the woods of Glenshalloch. It will be evident also on further study, that the deposition of these new beds upon the ground is conclusive of their superiority to the Mulloch-Hill rocks; for they constitute a definite zone, having the same strike as the Mulloch-Hill beds themselves, and forming an exterior coating to the latter, as do the Mulloch-Hill beds to the underlying rocks of the Ardmillan group. In developing the interrelations of the subformations composing the

inner shells of the Quarrel-Hill dome, as already described, we have had the advantage of possessing easily interpreted sections of long extent and tolerably continuous throughout. Among these newer and outer beds, on the contrary, the sections are much broken, and some of the component zones of the series are represented in isolated exposures of very insignificant extent. It follows, therefore, that while the general disposition and broader features of the strata are easily made out, we are unable to construct a complete ascending tabulation of the beds, or say with absolute certainty what special thicknesses of rock are locally wanting.

The area occupied by these beds is the extreme north-easterly angle of the Lower Palæozoic inlier, and is bounded on both its outer margins by faults of great magnitude, at the same time that it is more or less cut up by minor dislocations of dubious position. Nevertheless the component strata are exhibited in so many exposures that there can be no great question respecting their general arrangement, while they are of such a nature that they admit of very convenient subdivision in the field.

Broadly speaking, it may be said that the group is formed of two subdivisions—a lower subdivision of flaggy grits, sandstones, conglomerates, and calcareous flags, and a higher subdivision essentially composed of Graptolitic shales.

The *Lower Subdivision* forms a well-marked band about 200 yards in width, ranging parallel with the highest zone of the underlying Mulloch-Hill beds, from the cottage of Glenwells to the farmhouse of Newlands.

Its lowest beds are exposed at the little burn of Glenwells, to the southward of the Graptolitic mudstones we have referred to the Mulloch-Hill group, the intermediate beds being invisible for a distance of some 40 or 50 yards. These basal beds consist of thick-bedded sandstones and flags, with occasional zones of coarse conglomerate. The coarsest seams of conglomerate occur at the base of the section; but pebbly beds recur again and again in the succession. The matrix of the beds is sandy, and more or less calcareous. About 100 feet of these strata probably occur in the stream itself, between their first appearance above the Graptolitic mudstones and the neighbourhood of the cottage of Glenwells, where they are abruptly truncated by the great bounding fault of Kilkerran and Craighead.

The central and upper beds of this subdivision form several prominent ridges in the cultivated fields in their prolongation along the normal line of strike to the north-east, and in the wooded slopes between Glenwells and the farmhouse of Newlands. They afford, however, no serviceable exposures, except in the bed of the little stream whch drains the hill-slopes west of the farmhouse, where the pebbly gritstones are seen in place close to the farmhouse itself, while a series of soft flaggy beds is found a short distance lower down the stream.

An old quarry, a few hundred yards north-east of the farm, has been excavated in the higher zones of this subdivision. No section,

however, is visible; and the quarry itself is filled with fragments of the coarse gritstones collected from off the surface of the fields.

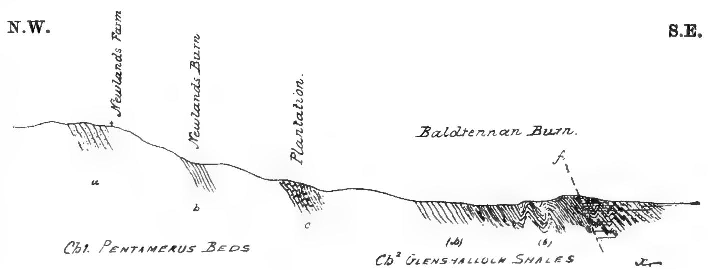
About twenty yards further, in the same direction, however, most valuable testimony is afforded us by a few limited sections in a small burn-course in a narrow strip of plantation. Here occur pale sandstones and calcareous flagstones, weathering of the same light yellow tint as the generality of the rocks of this subdivision. They split up under the hammer into angular fragments, and contain an abundance of casts of fossils. They yield examples of the characteristic Mulloch-Hill forms—*Atrypa hemisphærica*, Sow., *Nidulites favus*, Salt., *Rhynchonella cuneata*, Dalm., *Illænus Thompsoni*, Salt.,—and, in addition, a host of new and very striking forms unknown in the underlying series, including *Pentamerus lens*, *Pentamerus oblongus*, *Atrypa imbricata*, *Phacops Stokesii*, *Proetus Stokesii*, *Encrinurus punctatus*, &c.

Of the strata which follow immediately upon these *Pentamerus*-flagstones, we know very little further from this locality. An exposure of a few of the beds of the same zone occurs in the same plantation a few hundred yards to the northward; and a limited section of shales weathering to a purple colour, in the ditches at the edge of Glenshalloch Wood.

(iii.) *The Graptolitic Shales of Glenshalloch.*

The yellow-weathering *Pentamerus*-conglomerates, grits, and flagstones of Newlands are succeeded to the eastward by a thick mass of soft shales and flags, of a dark greyish-green colour. They

Fig. 23. *Section of the* Pentamerus *and Graptolitic Beds of Baldrennan Burn.*



x. Lower Carboniferous sandstones, shales, and limestone.
Cb^2. Glenshalloch shales.
 (*b*). Grey and striped Graptolitic shales and mudstones, with *Rastrites peregrinus*, *Monograptus fimbriatus*, &c.
 (*a*). Pale flagstones, non-fossiliferous.
Cb^1. *Pentamerus*-beds of Newlands.
 c. Yellow-weathering calcareous flagstone, with *Pentamerus oblongus*, *Atrypa reticularis*, *Encrinurus punctatus*.
 b. Pale blue flagstone.
 a. Coarse yellow conglomeratic gritstones.

occupy all the remaining portion of the Lower Palæozoic area, and

are well displayed in the branches of Baldrennan Burn, and in the smaller streams which drain the damp slopes of Glenshalloch Hill.

In the western branch of Baldrennan Burn the lowest visible strata of this higher subdivision consist of yellow-weathering pale-hearted flagstones, which are essentially identical with those of the underlying subgroup. These graduate upwards into a series of dark-grey Graptolitic shales, which extend downwards along the stream-course for a distance of about 150 yards, to the line of the great Craighead fault, where they are crushed against a series of flagstones, shales, and impure limestones, that possibly appertain to the Lower Carboniferous formations.

These Graptolitic shales dip at a steep angle, and appear to be more or less folded. Their united thickness may be estimated at about 200 feet.

Fossils are rare; the only forms are Graptolithina. These occur in some striped seams near the termination of the visible section. The chief forms collected include:—

Rastrites peregrinus, *Barr.*	Monograptus argutus, *Lapw.*
Monograptus crenularis, *Lapw.*	Diplograptus folium, *His.*
—— leptotheca, *Lapw.*	—— tamariscus, *Nich.*
—— gregarius, *Lapw.*	Climacograptus scalaris, *His.*
—— fimbriatus, *Nich.*	Retiolites.

Similar strata are seen again in the normal line of strike in the Glenshalloch branch of the Baldrennan Burn, immediately to the north of the Craighead fault, extending up the stream for some distance. The beds have all the characteristics of those of the last-mentioned locality, and afford precisely the same fossils.

The same Graptolitiferous shales are laid open in many of the small gullies that drain Glenshalloch Wood, striking in various directions and affording presumptive evidence of the presence of several cross faults. Along the roadway west of the burn of Glenshalloch they are stained of a purple colour, and are twisted round to the north-west over the arch of the main anticlinal and its accompanying faults. The beds have much the appearance of those of the shaly zones of the Upper Palæozoic rocks of the neighbourhood, and appear to have been mapped as such by the officers of the Geological Survey. Their lithological character and the occasional Graptolites they contain, however, place it beyond question that they are simply a slightly discoloured portion of the Graptolitic strata. The following forms have been collected from them by myself:—

Monagraptus fimbriatus, *Nich.*	Monograptus leptotheca, *Lapw.*
—— triangulatus, *Harkness.*	Climacograptus scalaris, *His.*

These Graptolitiferous shales are the highest beds of Lower Palæozoic age exposed in this area. The remaining angle of country lying between Glenshalloch Cottage and the point of convergence of the Craighead and High Newlands faults is wholly covered by drift and brushwood.

Summary.—Our study of the fossiliferous strata of the Girvan succession exposed in the inlier of Craighead and Mulloch Hill has resulted in the detection of an easily interpreted ascending sequence

from the Barren Flagstones of Quarrel Hill into the Graptolitic flagstones and shales of Glenshalloch. The strata of the inlier belong to two distinct groups in the succession, each group being strikingly individualized by lithological characters and by peculiar organic remains. The strata of all except the highest formation of this sequence are exposed in unbroken succession; while there is sufficient evidence available to fix the true place of this final division, and to determine broadly the thickness and general characters and fossils of its natural members. We have, that is to say, in this northern inlier the following ascending sequence:—

Ardmillan Series.
- B c. *Barren Flagstones* of Balweary and Quarrel Hill.
- B d. *Trinucleus Shales* of Drummuck and Lady Burn, consisting of:—
  1. The fossiliferous basal grits of Auldthorns.
  2. The *Trinucleus*-Musdtones of Lady Burn.
  3. The Sandstones and Starfish-beds of Quarrel Hill.

Newlands Series.
- C a. *The Mulloch-Hill Beds,* consisting of:—
  1. The Mulloch-Hill (High Mains) Conglomerate.
  2. The Rough-Neuk Shelly Sandstones.
  3. The Graptolitic Mudstones of Glenwells Burn.
- C b. *The Newlands Beds,* containing: –
  1. The *Pentamerus*-grits and Yellow Flags of Newlands.
  2. The Graptolitic (*gregarius*) Shales of Baldrennan and Glenshalloch Wood.

(D) Strata between the Saugh-Hill Fault and the Camregan Limestone.

With the invaluable aid afforded us by the complete and highly satisfactory succession among the *Trinucleus-*, *Brachiopod-*, and *Pentamerus*-groups we have last determined in the Craighead area, we now return to the rocks of the main plateau, and resume our study of the Lower Palæozoic strata lying to the south of the Girvan Valley.

The strata of this important region which yet remain to be described, lie between the Saugh-Hill fault and the bounding dislocation of Bargany, which has depressed the Carboniferous and Old Red Sandstone rocks of the valley of the Girvan. The area they occupy extends inland from the sea-shore near Shalloch to the village of Straiton upon the upper course of the Girvan Water, a distance of 12 miles; but its greatest breadth rarely exceeds three fourths of a mile. Within the area thus defined, the rocks under notice, as will be apparent upon a study of the maps, are arranged in a series of well-marked petrological zones, which form a succession of very narrow parallel bands, ranging longitudinally through the area from the Braehill fault on the west across the gorge of Penwhapple, and thence into the steep slopes of Bargany and Dailly, till they finally plunge, one by one, below the gently inclined conglomerates, red sandstones, and traps which make up the Old Red Sandstone group of the Hadyard Hills.

At first glance it would seem that nothing could be more simple than this arrangement. Rock-bands so distinctive in individual peculiarities, and so symmetrically disposed, are naturally expected

by the stratigraphist to be as easily and satisfactorily reduced to the natural order as were the regularly concentric and but slightly disturbed strata of the Craighead area. And, indeed, to a large extent, this expectation is justified by the event; for had the apparent inclination of the strata been trustworthy, there would have been no special difficulty in working out the entire sequence of the remaining rocks bed by bed; but, unfortunately, the repeated foldings and inversions, so palpable among the underlying Ardmillan strata of the Girvan plateau, are here continued and intensified; and the problem of the true sequence of the visible zones in the strata of the immediate neighbourhood of the Saugh-Hill fault, upon more extended examination, appears wellnigh unsolvable.

It will be seen from the map (Pl. XXV. 1) that a band of *Pentamerus*-grits and limestones (C c) forms what may conveniently be termed the longitudinal axis of the Lower Palæozoic region yet to be described. This band, which is traceable from end to end of its course, from the Braehill fault to the Hadyard Hills, forms a clear and easily recognizable horizon, or datum-line, to which to refer the less completely exposed strata of the region. North of this band, the strata, though inverted in inclination, present no special difficulties; but between it and the Saugh-Hill fault, the visible phenomena demand the most careful scrutiny.

This intermediate area is occupied by a series of hard gritstones and fine conglomerates, varied by occasional seams of flagstones, and thick bands of green, grey, and black Graptolitiferous shales. A kind of rude parallelism is evident among the beds; but the manner in which certain seams appear to thicken out in one locality, and to thin away in others, while elsewhere they seem at the first glance to be replaced by correspondent groups of wholly distinct petrographical characters, forces us to demand a much larger mass of testimony in favour of our conclusions than that which has satisfied us in the less disturbed areas already described.

(*a*) *Section of the Graptolitic Shales and Grits in Penwhapple Glen.*

The deep glen of Penwhapple affords by far the most satisfactory and continuous section of these dubious gritstones and shales. They follow in immediate geographical succession to the Barren Flagstones of that gorge already described, from which they are divided by the important Saugh-Hill fault.

Northward from the line of this fault they occupy the bed and banks of the stream for about a quarter of a mile of its course, until we reach the datum-line of *Pentamerus*-limestone last mentioned.

The most cursory examination of the grits and shales by one who has already studied the strata of Newlands and Glenshalloch, described in the preceding section, is almost sufficient to convince him that these beds, as seen in Penwhapple Glen, are identical in their lithological features with the yellow grits and Graptolitic flagstones of the northern locality; and whatever doubts he may feel as to their general correspondence with the northern strata are soon dispelled if he take the trouble to collect the fossils from these Pen-

whapple beds, as he will recognize amongst them some of the most peculiar and characteristic Glenshalloch forms.

Hence, if no unconformability intervenes to cause a stratigraphical break in the succession we have already developed (and, as we have seen, there appears to be no evidence in the northern inlier in favour of such a break), it is clear at the outset that between these Graptolite-bearing shales of Penwhapple and the Barren Flagstones, with which the Saugh-Hill fault has placed them in physical contact to the south, there are actually missing the entire subformations of the *Drummuck Mudstones* and the *Mulloch-Hill Sandstones*, a vertical extent of rock at least 600 feet in collective thickness.

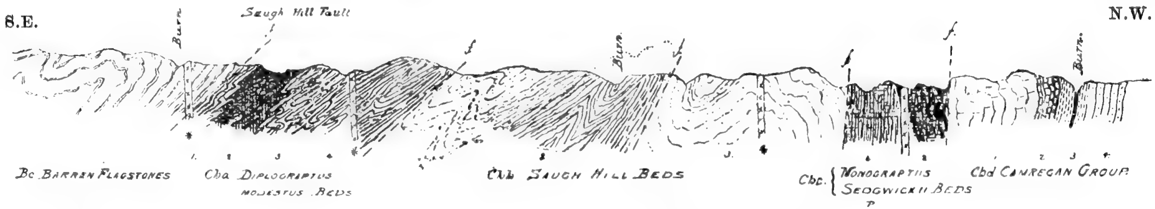
A more extended examination of these Graptolitic flagstones and grits, as here exhibited, while it will finally fix in the mind of the investigator the conviction of their general identity with the similar Glenshalloch series, will have the further result of showing him that some of the most conspicuous zones of rock apparent in that area are missing from this Penwhapple section, while other bands are here very conspicuous, which are apparently wanting in the Newlands and Glenshalloch area.

We have shown that, in spite of the innumerable inversions and dislocations determinable among the Ardmillan strata of the higher parts of Penwhapple Glen, there is nevertheless a generally ascending succession as we pass over the edges of the strata from south to north. As the strata now under examination are similarly affected by physical accidents, there is a strong *à priori* probability, amounting almost to certainty, that they will be found to be subject to the same general rule. We shall, indeed, show in the sequel that even the regularly disposed rock-bands on the northern side of the datum-line of the Camregan *Pentamerus*-limestone follow precisely the same rule of inverted succession.

Starting, therefore, from the line of the Saugh-Hill fault, let us study the Penwhapple section in detail, regarding the visible strata as inverted in position, and treating of the whole as a generally ascending sequence (fig. 24).

(Cba) *Diplograptus-modestus Shales.*—The strata which follow immediately upon the great dislocation form a thick zone of dark grey shales (Cba) with a few seams of flagstones. Its lowest beds are thick-bedded black mudstones, crowded with Graptolites in an excellent state of preservation. The basal beds of the group along the line of the fault itself are green flaggy rocks, concretionary and more or less calcareous. From these I have procured *Pentamerus* sp. The black mudstones themselves are crowded with *Diplograptus tamariscus*, Nich., *D. modestus*, Lapw., *Climacograptus normalis*, Lapw., *Monograptus tenuis*, Portl., *M. crenularis*, Lapw., *M. leptotheca*, Lapw., together with many fragments of Crustacea and Orthoceratites. These mudstones graduate upwards into the main mass of the grey shales through a small group of striped shales, containing an abundance of the same fossils with well-preserved Orthoceratites.

Fig. 24.—*Section of the Newlands Rocks of Penwhapple Glen.*



C. Newlands Series. :—

Cbd. Camregan beds.

(4) Thick-bedded yellow gritstones, non-fossiliferous.

(3) Purple mudstones, with zone of Graptolitic shale (*Rastrites-maximus* band), with *Rastrites maximus*, *Monograptus turriculatus*, &c.

(2) Calcareous flagstones and shales (Camregan or Upper *Pentamerus*-limestone), with *Pentamerus oblongus*, *Strophomena applanata*, &c.

(1) Thick-bedded grey and yellow grits and sandstones, with *Rhynchonella cuneata* &c.

Cbc. *Monograptus-Sedgwickii* beds.

(2) Black carbonaceous and pyritous shales and mudstones, with *Monograptus Sedgwickii*, *Rastrites peregrinus*, &c.

(1) Grey and green mudstones, non-fossiliferous.

ff. Faults.

Cbb. Saugh-Hill beds.

3. Thick-bedded grey grits, with small pebbles.

2. Flaggy shales, non-fossiliferous.

1. Coarse grits and flagstones, pale grey, with occasional pebbly seams.

Cba. *Diplograptus-modestus* shales.

4. Grey and green shales, generally unfossiliferous.

3. Striped shales, with Graptolites, Phyllopods, and Orthoceratites.

2. Black carbonaceous and pyritous mudstones, with *Diplograptus modestus*, *Monograptus leptotheca*, &c.

1. Grey and green mudstones and shales, with *Pentamerus* sp.

B. Ardmillan Series :—

Bc. Barren flagstones.

Upper zones with *Diplograptus truncatus*.

* Basaltic dykes.

In the grey shales themselves Graptolites are remarkably rare. The only forms collected by myself are *Diplograptus modestus*, Lapw., and *Diplograptus*, sp.

(Cbb.) *Grey Flags and Grits.*—The grey shales are followed by a similar thickness of hard grey gritstones (Cbb). Many of the beds are three or four feet in thickness, and are filled with small quartz pebbles about the size of a pea. They are associated with more thinly bedded flagstones without quartz pebbles. The beds are usually of a pale grey interiorly, and the majority weather exteriorly in the stream-course to an orange-yellow tinge. They are greatly twisted and broken; and no reliable estimate can be formed of their thickness. No fossils are known from this group.

This grit series is succeeded by a second zone of the grey shales so characteristic of the group. These are very similar to those of the first zone, but are more micaceous and iron-stained; but, to judge from the general disposition of the strata (see fig. 24), they are merely a repetition of the same beds. They contain no visible fossils in this locality.

A second grit band follows, resembling the first band in all essentials, but containing more of the thick-bedded pea-grits, some bands of which are at least six feet in thickness.

(Cbc.) *Monograptus-Sedgwickii Mudstones.*—Above follows the third and final shaly zone of the series. This is composed of a most conspicuous group of grey and black shales, apparently more than a hundred feet in thickness. The lower or southern half of the band is formed of greyish-green shales identical with those of the previous shaly zone, and like them wholly devoid of organic remains. The upper or northern half, however, is most unique in its lithological features.

It consists essentially of soft shaly mudstones, containing a large proportion of carbonaceous matter; and impregnated with sulphate of iron. The entire group is stained of a deep iron-shot colour, and is so excessively crushed and contorted that the bedding can only be made out with the utmost difficulty. Calcareous matter is occasionally present in notable quantity; and large nodular concretions are abundant in the steep cliffs of the rock which overhang the right bank of the stream.

Graptolites are abundant, but are most difficult of extraction, in consequence of the crushing to which these beds have been subjected; while fragments of Crustacea and Orthoceratites are occasionally seen.

The Graptolites as a whole are very distinct from those of the black shale near the Saugh-Hill fault at the base of our section. A few of the forms there obtainable are still present, viz.:—

Diplograptus tamariscus, *Nich.*	Climacograptus normalis, *Lapw.*
Monograptus tenuis, *Portl.*	Monograptus attenuatus, *Hopk.*

But they are accompanied by a host of other forms unknown in the basal beds, chiefly the familiar species:—

Rastrites peregrinus, *Barr.*	Monograptus intermedius, *Carr.*
—— hybridus, *Lapw.*	—— spiralis, *His.*
Monograptus Sedgwicki, *Portl.*	Diplograptus folium, *His.*
—— Hisingeri, *Carr.*	—— palmeus, *Barr.*
	—— Hughesii, *Nich.*

The soft black mudstones terminate abruptly to the north against the series of grits and sandstones which form our datum-zone of the *Pentamerus*-beds of Camregan.

Our study of the Graptolitic shales and gritstones of Penwhapple have thus resulted in showing us that in this locality there are two distinct Graptolitiferous zones, one at each end of the section—the earlier one characterized by *Diplograptus modestus*, Lapw., and a few other forms, and the later one by *Monograptus Sedgwickii*, Portl., and its usual associates. These two terminal zones are here divided from each other by an intermediate zone of barren pale-hearted and pebbly gritstone.

The *M. Sedgwickii* bed at the summit of the section is clearly absent from the Glenshalloch area; nor is there any thing in that district we can satisfactorily parallel with the central grits and shales of Penwhapple. The only strata, therefore, that we may regard as possibly common to our Glenshalloch and Penwhapple sections are the grey shales of the first zone; and even of these the black *D. modestus* mudstones at their base are unseen in the northern inlier.

If, therefore, the Newlands *Pentamerus*-grits which underlie the main mass of the Glenshalloch shales, conglomerates, and limestones are present in the southern area, we can only expect to find them in the immediate neighbourhood of the Saugh-Hill fault.

(*b*) *Confirmatory Section of Saugh Hill.*

Eastward of Penwhapple Glen no good sections of these strata are visible; but westward their beds are greatly developed and are fairly exhibited to the investigator.

Saugh-Hill area (*Diplograptus-modestus* Shales).—Excellent sections of the basal zone of grey shales are seen in the Tralorg Burn. The inverted beds dip with tolerable regularity towards the line of the Saugh-Hill fault; but we find evidence that the great dislocation crosses different horizons along its course, in the presence of soft white mudstones and shales which are unknown in the Penwhapple section; while occasional bosses of a coarse pebbly conglomerate are found along the same line.

As the line of grey shales is followed over the higher ground to the west, the section becomes obscured by vegetation, and we find no exposure of the *Diplograptus-modestus* band until we reach the head of Saughill Burn, more than a mile to the westward, where the many small drains afford a few insignificant exposures.

On the west side of Saughill Burn, at the precise point where the Saugh-Hill fault is cut off by a transverse dislocation, a good section of the Graptolite-bearing beds of a part of the grey-shale band is shown in the miniature cliffs by the side of the almost obliterated hill-road. Here dark carbonaceous shales dip into the Saugh-Hill fault at a

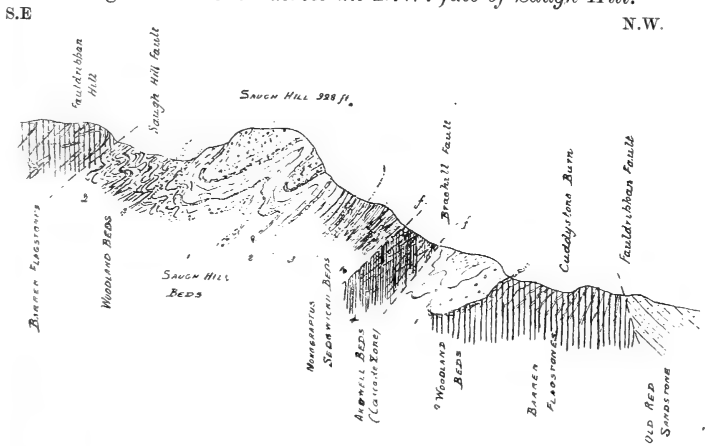
medium angle, and afford proofs of the extension of our lowest Penwhapple shale-band to this spot, both in their petrographical features, and the presence of

Diplograptus tamariscus, *Nich.*	Monograptus cyphus, *Lapw.*
—— modestus, *Lapw.*	—— gregarius, *Lapw.*
Climacograptus normalis, *Lapw.*	—— tenuis, *Portl.*

and the generality of the Penwhapple forms (see fig. 25).

At this point the fault of Saugh-hill Burn brings the band to a sudden termination, the Ardmillan beds occupying the hill-slopes immediately to the westward.

Fig. 25.—*Section across the N.W. face of Saugh Hill.*



Ardmillan Series:—

Ba⁴. Ardwell Beds. Thin-bedded mudstones and conglomeratic grits of the Cascade-zone, with *Dicellograptus Forchhammeri*, *Dicranograptus Nicholsoni*, &c.

Bc. Barren Flagstones, with *Nematolites*.

(C) Newlands Series:—

Cba. Woodland beds.

(2) Craigskelly conglomerate?

(3) Striped shales, with *Diplograptus modestus*, *Monograptus leptotheca*, &c.

(4) Grey shales, non-fossiliferous.

Cbb. Saugh-Hill beds.

(1) Grits and flagstones and quartz conglomerate, grey, with *Climacograptus* &c.

(2) Calcareous band.

(3) Pale yellow sandstones, grits, and conglomerates.

Cbc. *Monograptus-Sedgwickii* beds.

1. Grey and green shales and thin-bedded flagstones, with *Rastrites peregrinus*, *Diplograptus palmeus*, &c.

Penwhapple Grits and Shales.—Returning therefore to our continuous section in Penwhapple Glen, we next proceed to define the distribution of the succeeding zones of pebbly grits which there

intervene to separate the grey-shale zone from the *M.-Sedgwickii* mudstones.

The yellow grits, imitating precisely in the gentle curvature of their strike the range of the grey shales to the south, sweep up from the banks of Penwhapple into the hill of Camregan, forming a broad and well-marked mound upon the surface of the ground. Thence they are followed continuously along the ridge into the summit of Saugh Hill, forming a broad mound-like ridge, from 700 to 900 feet in height and more than two miles in length, which looks down upon Girvan and the cultivated slopes of the Brae. At its eastern extremity the extent of surface floored with this band of coarse grits is not more than 300 feet in width; but as it proceeds to the eastwards, it rapidly enlarges its diameter, till finally, upon the summit of Saugh Hill (fig. 25), it cannot be less than 600 feet wide: and the group attains here a geographical importance which has suggested to me the title of *Saugh-Hill Group* as the collective name for the entire Gritstone and Graptolitiferous series.

The coarse grits are exposed in a host of quarries and natural sections along the ridge; and much additional knowledge of the physical characteristics of the group is obtainable. In addition to the coarse and more or less flaggy gritstones of Penwhapple Glen, we have here actual beds of conglomerates with pebbles an inch or two in diameter and peculiar breccias made up of angular fragments of quartz, gritstones and shales, imbedded in a strange matrix of a greyish-white colour. Some of the associated grits are of great thickness, but are generally separable into large parallel flags. The entire group is very sandy in character; the majority of the beds weather to an orange-yellow, and occasionally even to a faint pink colour. Fossils are said to have been procured from these beds; but I have never yet been able to detect a single fragment of anything organic within them.

The great width of the band upon Saugh Hill is undoubtedly due to the fact that the beds are repeatedly folded. A peculiar rock, having the general character of a bastard limestone, makes its appearance again and again as we cross the band transversely, and affords a good idea of the number of hidden folds.

The narrow diameter of the same zone near Penwhapple is in all probability due to faulting, as there are certainly several strata upon Saugh Hill that are wanting in our Penwhapple section.

Monograptus-Sedgwickii Mudstones.—Between the summit of the Saugh-Hill ridge, which is occupied by the yellow grits and sandstones described, and the general datum-line of the axial Camregan limestone group, few sections are visible; but all the evidences they afford us concur to prove that this interesting band of country is mainly occupied by the final or *M.-Sedgwickii* band of the Saugh-Hill group. The second grit of Penwhapple cannot be traced for any great distance westwards; and its place is occupied by dark shales, apparently of the *M.-Sedgwickii* zone, within a quarter of a mile of the glen. Grey flaggy shales similar to those in contact with these grits are traceable bounding the Saugh-Hill sandstones along the northern

slopes of its prominent ridge until we reach the north and south fence which separates the properties of Killochan and Bargany. A little to the west of this fence the *M.-Sedgwickii* beds are seen *in situ*, retaining all the characteristics they exhibited in Penwhapple glen, and affording:—

Rastrites hybridus, *Lapw.*	Diplograptus palmeus, *Barr.*
Monograptus Sedgwickii, *Portl.*	—— tamariscus, *Nich.*
—— spiralis, *Gein.*	Climacograptus normalis, *Lapw.*
—— lobiferus, *M'Coy.*	

The northern slopes of Saugh Hill are occupied by grey shales and flags probably a little lower in the series. These are well exposed in many sections on the hill-face, very conspicuous from the valley below. They contain few fossils, the chief forms I have been able to procure from them being *Monograptus gregarius*, Lapw., and *Rastrites peregrinus*, Barr.

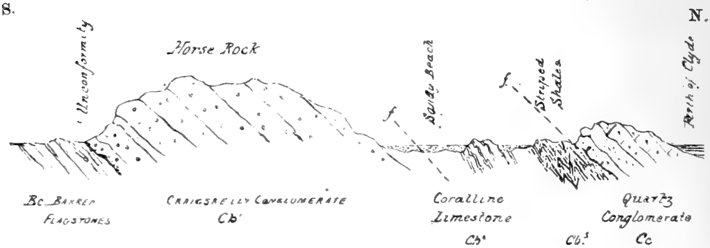
(c) *Coast-area of Shalloch and Woodland.*

The broad band of yellow gritstone and grey Graptolitiferous shales we have traced from the gorge of Penwhapple into the heights overlooking the seaport of Girvan is abruptly truncated, where it attains its widest geographical extension at the western extremity of Saugh Hill, by the transverse fault of Saugh-Hill Burn. The area through which its strata would naturally be prolonged is occupied by the older and very distinct Ardmillan Shales, which strike almost at right angles to the Saugh-Hill band. These Ardmillan strata, after gaining their normal strike in Piedmont Glen, are continued to the west in the coast-platform of Shalloch and Ardwell as far as the distant headland of Woodland and Kennedy's Pass, between which, as we have shown, they attain their most typical development in the Girvan region.

The great fault of Braehill and Dailly, which forms the southern boundary of the Carboniferous and Old Red beds of the Girvan valley, and which crosses the front of Saugh Hill at the head of Cuddystone Burn, comes upon the shore at Shalloch Forge and is prolonged south-westwards down the entire length of the coast-platform. It runs in a straight line parallel with the edge of the shore, and throws down against the flaggy Ardmillan series a very different set of beds of a most peculiar petrological character. They consist of massive boulder-conglomerates, pebbly grits, and striped shales. The hard and intractable nature of these peculiar strata, as contrasted with the more easily eroded Ardmillan beds with which they are in contact, has resulted in their being preserved as a line of conspicuous reefs, which rise up boldly out of deep water, and form a protecting fringe along the seaward edge of the platform. At high water they compose a line of long and narrow islands, against which the waves dash their fiercest, while the interior parts of the platform, occupied by the Ardmillan series, are covered from sight by the less agitated waters which force their way through the many openings in this natural breakwater.

1. *Shalloch Forge.*—At the back of the blacksmith's shop of Shalloch, where the Braehill fault comes upon the sea-shore, we find excellent exposures of the strata of this conspicuous protecting series. The general succession there apparent is given in the following section (fig. 26).

Fig. 26.—*Section of the Rocks of Shalloch Forge.*



B. Ardmillan Series:—
  Bc. Barren flagstones.
C. Newlands Series:—
  Cba. Woodland beds.
    Cba¹. Coarse green boulder-conglomerate of Craigskelly.
    Cba². Coralline limestone, with *Pentamerus oblongus* &c.
    Cba³. Striped shales, with *Diplograptus modestus, Monograptus leptotheca*, &c.
Cc. Saugh-Hill beds.
  Cc¹. Quartz conglomerate of Shalloch Forge.
  f f. Faults.

The beds which have the appearance of being lowest in the succession are certain green flagstones and shales (Bc), lithologically similar to those of the Barren Flagstones of the Ardmillan group and the green flagstones occasionally found in the Graptolitiferous zones of the Saugh-Hill beds. They are only seen at low water, immediately to the south of the rugged boss of the Horse Rock, which at high tide forms the most northerly of the protecting fringe of islands already referred to. Of these green flagstones only about 30 feet are seen, and they dip at an angle of about 45 degrees to the northward, and are succeeded, with a slight unconformity, by the remarkable mass of boulder conglomerate of which the Horse Rock itself is made up. This conglomerate is from 50 to 60 feet in total thickness, and contains many interbedded seams of gritstones, which show that the general inclination of the rock is almost identical with that of the flagstones below. The main mass of the conglomerate is made up of well-rounded boulders varying from one inch to a foot and a half in diameter. They consist of pieces of granite, porphyry, felstone, greywacke, shale, Lydian stone, quartz, and jasper, imbedded in a coarse sandy matrix of a dark green colour and excessively indurated. In its general aspect the rock reminds us of the Benan Conglomerate, and also in the special association of its enclosed boulders, but it is altogether harder and much more firmly compacted than is generally the case with that deposit.

Above this Horse-Rock conglomerate there is a break in the

section of some 30 or 40 feet, and the next strata seen are very different in their mineralogical characters. They protrude in little bosses from the sand of the small beach immediately north of the Horse Rock itself, and consist of a few feet of highly calcareous flagstone, or "bastard limestone," much altered and disturbed, but abounding in casts of *Pentamerus oblongus* and other Brachiopoda, together with well-preserved examples of *Alveolites Labechei, Favosites gothlandica,* and other corals.

After a second hiatus of less geographical importance than the former, these Coralline Limestones are succeeded by a thin group of Graptolitiferous shales, which are traceable from the back of the smithy, parallel to the two zones already noticed, for about 60 yards out to sea. They consist of dark greyish-blue and somewhat flaggy beds veined by seams of carbonaceous matter. They are thrown into innumerable wrinkles and contortions, which are beautifully exhibited on the wave-washed shore at the back of the Forge.

These shales contain an abundance of fairly preserved Graptolites of the species *Diplograptus modestus*, Lapw., *Climacograptus normalis*, Lapw., *Monograptus tenuis*, Portl., and *M. cyphus*, Lapw., together with forms of *Dictyonema* and *Orthoceras.*

The Graptolitic shales are followed abruptly by a conspicuous group of conglomeratic sandstones. They form a broad band lying to the north of the shales, and ranging outwards from the roadway into the deep water beyond the Horse Rock. These superior beds are emphatically bedded sandstones, much softer and looser in texture than the generality of the Lower Palæozoic rocks; they contain an abundance of white quartz pebbles, often rounded, but occasionally angular, scattered confusedly through the main body of the rock. The basal beds are filled with patches and angular fragments of the underlying shales, and the two formations are dovetailed into each other in a most intricate manner, rendering the detection of their natural relationship more a matter of speculation than of absolute certainty.

The base of these conglomeratic sandstones must originally have been unconformable with the Graptolitiferous shales with which they are in contact. Although the two strikingly distinct rock-groups are greatly crumpled and intermixed along the line of junction, a cautious study of the phenomena apparent places the fact of their original discordance almost beyond question.

Abundant small fragments and many large slabs of the neighbouring grey shales occur in the heart of the sandstones, sometimes lying parallel with the plane of bedding, sometimes inclined at a wide angle thereto. Again, the lowest visible zone of the sandstone conglomerate is filled with pieces of the same striped shales, which are surrounded and buried up by the coarser pebbly rock, as if they had projected from the sea-floor at the time of the formation of the sandstone, and had been enveloped and buried by the latter being deposited around and above them. Thus it is highly probable that the conglomeratic sandstones which now dip generally with the underlying beds were originally somewhat discordant with them,

and that their present steep dip is owing to the intercalary fault we have referred to. This fault, however, while it has permitted these overlying beds to be crushed into a general correspondence in inclination with the underlying strata, has not actually allowed of their removal far from their original position, the angular fragments included in the sandstones being primarily derived from the striped shales with which they are still in contact.

This quartz conglomerate is, in all likelihood, identical with a similar band which is found at the base of the Saugh-Hill rocks, running from the head of Saugh-Hill Burn to the eastern slopes of Camregan Hill. It is there divided from the striped and grey shales of the *Diplograptus-modestus* beds by a narrow strip of flaggy greywackes with *Climacograptus normalis*. (See Map, Pl. XXV. 1, and Section, fig. 25.)

Turning next to the neighbouring Graptolitic shales and associated strata of Shalloch Forge, and bearing in mind the fact of the fault and possible unconformity between them and the conglomeratic sandstones, we find that they present us with no further difficulty. The observer who has made himself familiar with the section of the Saugh-Hill shales and gritstones in Penwhapple Glen will at once refer the striped shales here exhibited to the zone of striped shales in the immediate neighbourhood of the great fault of Penwhapple; for not only are the strata lithologically similar in the two localities, but their fossils are absolutely identical species for species.

The underlying Penwhapple zone of black mudstone should here be found in the blank which intervenes between the striped shales and the Coralline limestone with *Pentamerus*, which latter affords an additional link of correspondence with the Penwhapple section, where we find the merest fragment of the Coralline seam in the lowest concretionary rock with *Pentamerus* and Corals.

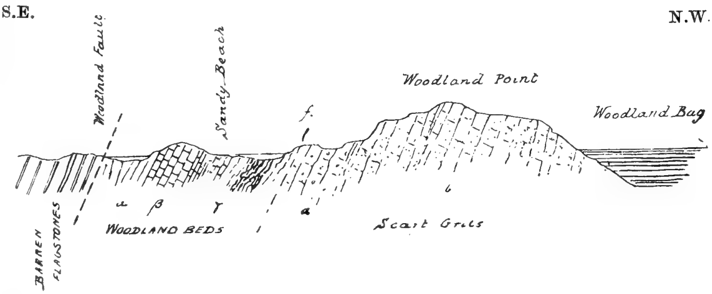
In the Saugh-Hill section of Penwhapple this Coralline seam is the lowest rock exposed; but if no hidden fault intervene between the bed, as here exhibited, and the coarse Horse-Rock conglomerate, we are here enabled to descend much lower in the succession, and to provisionally locate the boulder-beds of the Horse Rock immediately below the base of the Penwhapple and Saugh-Hill sections, and immediately subjacent to the Coralline or *Pentamerus*-band.

2. *Craigskelly*.—The boulder-bed of the Horse Rock is prolonged south-westward into the long mound-like boss of Craigskelly. This forms a low rugged island at high water, but is connected with the shore by a sandy beach at low states of the tide. The coarse strata of the Horse Rock are here perpendicular in attitude, and have a transverse diameter at least double that they possess in the former locality. The boulder-beds already described occupy the south-eastern half of the island; while all the western half is formed of hard-bedded gritstones several feet in thickness, plunging suddenly downwards into deep water. These gritstones weather to a yellowish tint, and a few have the peculiar pink tinge which marks many of the rocks of Saugh Hill, with which also they agree in the pale grey

tint of their unweathered interior. In spite of their forbidding aspect, they contain many fragments of well-marked fossils, principally *Strophomena grandis, Atrypa reticularis, A. hemisphærica, Dictyonema.*

3. *Woodland Point.*—The line of reefs formed by these Saugh-Hill strata is broken beyond the boss of Craigskelly by the wide opening of Shalloch Bay. Near the centre of this bay, however, a similar band of hard yellow gritstones rises again into view, forming the two small islands of the Scart rocks, which are isolated from the shore even at lowest tides. At the succeeding headland of Woodland Point, the band comes for the last time upon the shore-line, and we are here presented with the most fossiliferous exposure of the Lower Saugh-Hill strata in the Girvan region.

Fig. 27.—*Section of the Strata at Woodland Point.*



C. Newlands Series:—
  Scart grits (? Saugh-Hill beds).
    (*b*) Thick-bedded pale-hearted gritstones, with occasional flags.
    (*a*) Quartz conglomerate and pebble-beds.
  Woodland beds.
    γ. Thin-bedded soft shales and mudstones, with carbonaceous seams: *Monograptus leptotheca, Climacograptus normalis,* &c., *Orthoceras, Encrinurus, Atrypa.*
    β. Calcareous flagstones (Woodland or Lower *Pentamerus*-limestone), crowded with *Stricklandinia lens, Pentamerus oblongus, Strophomena grandis,* &c.
    α. Calcareous flags and shales, with few fossils.
B. Ardmillan Series:—Barren Flagstones.
  f. Faults.

The headland itself is composed of a long reef of gritstone, which at low water is united to the main shore-line by a sandy beach, but at high water forms a rugged island of the type of Craigskelly. The above section (fig. 27) affords a general idea of the disposition of the strata at this interesting locality.

The main body of the reef is formed of a series of yellow-weathering gritstones (*b*), in beds varying from 2 to 4 feet in thickness. They are pale-hearted and very intractable under the hammer; but the matrix is not coarser than that of the average gritstones of Saugh Hill and Penwhapple. The breadth of the reef occupied by these massive gritstones cannot be less than 100 feet; but the beds, through varying but little from the perpendicular, afford indications

of folding and dislocation. The inner edges of the reef are formed by coarser beds (a), which are filled with abundant fragments of quartz, gritstone, and igneous rocks, and deserve rather the title of coarse pebbly conglomerates.

Between these conglomerates and the beds next to be described, the phenomena visible upon the ground give rise to the suspicion that a fault is present; but of its magnitude and effect in interrupting the natural sequence no evidence is forthcoming.

The low and partly sand-covered area lying between these conglomerates and the great Braehill fault, which brings up the Barren Flagstones of the much older Ardmillan series, is occupied by a series of calcareous strata most prolific in fossils. These are exposed in some insignificant bosses of rock that are accessible only at low water, and in occasional patches of strata which project here and there through the floor of the sandy beach.

Next to the intermittent conglomeratic bands last noticed follow certain green flaggy shales (γ), striped with lines of carbon and seams of calcareous matter. Only a few feet of these beds are exposed, but they are most prolific in beautifully preserved Graptolites, especially *Diplograptus modestus*, Lapw., *Climacograptus normalis*, Lapw., *Monograptus tenuis*, Portl., *M. gregarius*, Lapw., *M. leptotheca*, Lapw., together with fairly preserved Brachiopoda and forms of *Orthoceras*.

These beds are followed to the south-east by soft green shales, highly calcareous, and abounding with most exquisitely preserved examples of *Strophomena grandis*, *Atrypa reticularis*, *A. imbricata*, *Orthis elegantula*, and *Leptæna quinquecostata*.

They are succeeded by a thickness of about 30 feet of highly calcareous flagstones or limestones (β), which form prominent ridges on both sides of the peninsula. These limestone flags are arranged in beds which vary from a foot to an inch in thickness, and are almost made up of organic remains. Some of the beds are a compacted mass of *Stricklandinia lens*: others are crowded with *Strophomena grandis*; but all are indeed most astonishingly prolific. Here I have collected *Stricklandinia lens*, *Pentamerus oblongus*, *Atrypa reticularis*, *A. imbricata*, *Bronteus*, *Encrinurus punctatus*, *Holopella*, and a host of Corals, Encrinites, and *Orthocerata*.

About 30 or 40 feet of these *Pentamerus*-limestones are here exposed, dipping at an apparent angle of about 60° to the south-west, that is to say into the line of the great longitudinal fault which here intervenes to separate them from the ancient barren flagstones of the Ardmillan series.

That these *Pentamerus*-limestones, Graptolitic shales, and massive gritstones belong to the same special group as the rocks forming the more easterly portions of this rock-reef as exposed in Craigskelly and its neighbourhood is absolutely certain. The rocks of this reef have a special character of their own, easily recognizable upon the ground, which distinguishes them at sight from the flaggy Ardmillan strata with which they are in unnatural contact, while the fossils are the same along the entire extent of the reef.

If the Graptolitiferous striped shales of Shalloch Forge are, as I have already argued, the highest visible beds of these Craigskelly rocks, the analogy furnished by the structure of the area already studied would lead us to infer that the band of Woodland limestone which lies upon the opposite margin of the band along the line of the great fault must be the lowest visible zone of the series as here exhibited.

It is not wholly impossible, however, that the rocks of this reef are actually arranged in the anticlinal form suggested by the diverging dips upon the opposite margins. If so, the Woodland limestone would form part of the Coralline lime-band of the Horse Rock and the Woodland grits, being lost in the fault at the base of that limestone, a part of them only being seen upon the north-western flanks of Craigskelly, while the boulder-band of the Horse Rock would then form the lowest bed of the series. But the presence of the soft Graptolitic mudstones between the Woodland limestone and the Scart grits, the similarity of the basement-beds of the latter to the quartz conglomerate of Shalloch Forge, together with the general correspondence in petrological characters of the Scart grits and those of Saugh Hill, all concur to favour the theory of the general identity of the Woodland limestone and the Coralline band. In this case the sequence of the Newlands Series along the shore-line will stand as follows :—

Cbb. Saugh-Hill beds.	2. Scart Grits and Flagstones.
	1. Quartz conglomerate.
Cba. Woodland beds.	4. Grey non-fossiliferous shales of Penwhapple.
	3. Striped and black Graptolite-shales and mudstones.
	2. Woodland Limestone.
	1. Craigskelly Boulder-conglomerate.

On this view we are able to reconcile several important physical facts obtainable within the Girvan region.

(1) At the south-eastern extremity of the Horse Rock, where the Craigskelly boulder-bed is seen in contact with the underlying green flagstones and shales, there is a distinct appearance of unconformability, the coarse boulder-beds resting upon the slightly eroded faces of the older beds.

(2) On the north-western flank of Saugh Hill a boulder-conglomerate, probably identical with that of Craigskelly, rests at once upon the Barren Flagstones of Cuddystone Burn (see fig. 25).

(3) The united thickness of the Woodland and Saugh-Hill subformations, thus arranged, agrees closely with that of their representatives, the coarse conglomerates and yellow flagstones of Newlands and Craigwells, in the northern inlier.

(4) An unconformability at the base of the Craigskelly conglomerate rids us of the necessity for assuming the presence of the Drummuck and Mulloch-Hill formations south of the Girvan valley, and thus reduces the theoretical downthrow of the Saugh-Hill and Woodland faults to comparative insignificance.

It is interesting to notice also that this special stratigraphical break occurs at precisely the same palæontological horizon as that which divides the so-called Lower and Upper Silurian of Southern Britain.

If these conclusions are accepted, we have in the strata belonging to the same general group as the Newlands and Glenshalloch beds of the northern inlier the following zones south of the datum-line of the Camregan limestone :—

Cbc. *Monograptus Sedgwickii* beds. 100 feet.	2. Thick zone of Graptolitic shales, aluminiferous and concretionary, with *Monograptus Sedgwickii*.
	1. Grey and green, non-fossiliferous shales and mudstones.
Cbb. Saugh-Hill Grits and Shales. 200 ft.	3. Coarse yellow sandstones, flags, and grits, with pebbles.
	2. Pale yellow grits and flags, with a zone of impure calcareous rock.
	1. Quartz conglomerate and grits.
Cba. Woodland beds. 200 feet.	4. Green, non-fossiliferous shales.
	3. Black and striped Graptolitic shales.
	2. Woodland or Lower *Pentamerus*-limestone.
	1. Craigskelly conglomerate.

(E) Strata North of the Camregan Limestone.

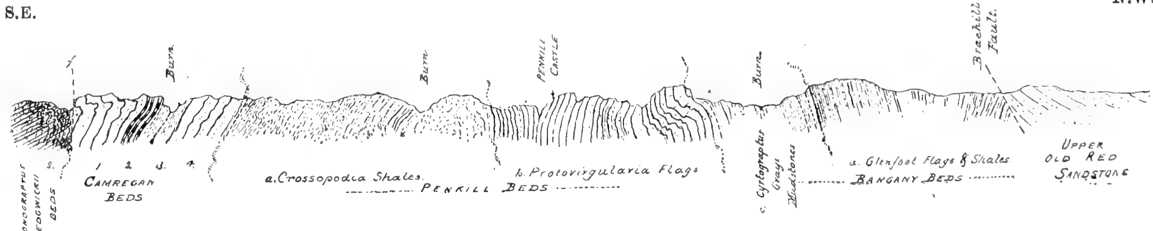
(*a*) *The Camregan Limestone and its associated Strata.*

Having completed our examination of the shattered and more or less incomplete sections of the wide band of Saugh-Hill rocks, we now enter upon the study of those found in the area lying immediately to the northward. This new area is, by contrast, one of great geological simplicity, where, as a consequence, our task of determining the order of succession is comparatively easy and satisfactory (Plate XXV. 1).

It is formed of a narrow belt of Lower Palæozoic strata, about 12 miles in length, lying between the band of dark mudstone with *Monograptus Sedgwickii*, which forms the terminal member of the Saugh-Hill Group, and a line drawn parallel with this zone about half a mile to the northward. The belt of country thus defined, as we have more than once pointed out, is occupied by several parallel zones of rock, individualized by well-marked petrographical and palæontological peculiarities, and traceable longitudinally through the area from the Braehill fault on the west to the Old Red Sandstone of the Hadyard Hills on the east.

In the complete transverse section of these strata afforded by the gorge of Penwhapple to the south of the old castle of Penkill (fig. 28) we find the beds of the soft crumpled mudstones of the *M.-Sedgwickii* zone crushed suddenly against a group of massive gritstones and flags to the north. The first beds of this new group weather of a yellow tinge, and vary from 2 to 4 feet in thickness. Interiorly they are of a pale bluish-white colour, agreeing in this respect precisely with the thick-bedded gritstones of Saugh Hill. The massive grits immediately above the *M.-Sedgwickii* zone are almost perpendicular, and the line of contact, in which the crushed and contorted mudstones and shales of the latter are sud-

Fig. 28.—*Section of the Lower Portion of Penwhapple Glen.*



D. Dailly Series.
- Db. Bargany beds.
  - Dba. Glenfoot pale flagstones and shales, non-fossiliferous.
- Da. Penkill beds, 1000 feet.
  - (3) *Cyrtograptus-Grayi* mudstones. Purple and green mudstone, with *Retiolites*, *Cyrtograptus*, &c.
  - (2) *Protovirgularia*-flags and greywackes. Grey and green flagstones, greywackes, and shales, with *Protovirgularia* and *Monograptus exiguus*.
  - (1) *Crossopodia*- or purple shales. Thin-bedded purple and green shales and mudstones, with *Crossopodia scotica*, *Monograptus galaensis*, &c.

C. Newlands Series.
- Cd. Camregan beds.
  - (4) Camregan Upper or pale gritstones.
  - (3) Purple mudstones, with *Rastrites maximus*.
  - (2) Camregan or Upper *Pentamerus*-limestone.
  - (1) Lower Camregan or *Rhynchonella*-grits.
- Cc. *Monograptus-Sedgwickii* beds.
  - (2) Black pyritous shales, with *M. Sedgwickii*.
  - (1) Non-fossiliferous green shales.

denly succeeded by the gritstones, has all the appearance of a fault. The gritstone zone extends down the burn for a distance of about 60 or 70 yards. Its beds are all much convulsed and disturbed, so that no reliable estimate can be formed of their thickness. They are quite barren in their central portions; but in their lower beds, in the neighbourhood of the *M.-Sedgwickii* band, their weathered edges are crowded with casts of *Rhynchonella*, associated with rarer examples of *Orthis* and *Strophomena*.

These thick-bedded yellow *Rhynchonella*-grits are followed by a group of calcareous flagstones which have an apparent thickness of about 50 feet. Their more southerly beds are much shattered, but the terminal zones dip steadily to the southward at an angle of from 60° to 70°. A beautifully complete section of these beds is afforded by the cliffs on the right side of the gorge.

The lower or southerly beds are nodular, but they contain no fossils; but the upper beds, which are so highly calcareous that they may be regarded as impure limestones, are many of them a mass of corals and shells.

The genus *Lindstrœmia* or *Petraia* occurs in myriads, in association with *Pentamerus*, *Atrypa*, and *Strophomena*, buried in a rock of extraordinary toughness and compactness under the hammer.

The terminal seams are blue shales, strongly calcareous, the irregular laminæ of which are covered with trails and markings of Annelida. In these shales fossils are less plentiful than in the limestone flags, but they are more easily extracted and more completely preserved.

Here we find the usual Upper Girvan fossils:—

Encrinurus punctatus.	Halysites catenulatus.
—— variolaris.	Atrypa hemisphærica.
Bronteus Brongniarti.	—— reticularis.
Illænus Thomsoni, &c.	Pentamerus oblongus.

This highly fossiliferous zone I denominate the Penkill or Camregan limestone, after the localities where its fossils have been most carefully studied, and which will be presently noticed more particularly.

In this typical locality in Penwhapple Glen, this Camregan limestone is succeeded to the northward by a zone of purple and green mudstones of about the same thickness as the limestone zone below it. These mudstones contain merely a few Annelid-markings throughout their entire vertical extent, except in one thin seam of dark carbonaceous shales near their centre, about a foot and a half in total thickness.

This carbonaceous seam may be followed by the eye across the stream from the east to the west bank of the gorge, and thence up the course of a small runnel descending the steep slope to the left, where its laminæ are laid open and may be studied *in situ*. It here contains an abundance of fairly preserved Graptolithina, together with occasional examples of Phyllopodous Crustacea. From these beds I have collected, among other forms:—

Rastrites maximus, *Carr.*	Monograptus runcinatus, *Lapw.*
Monograptus turriculatus, *Barr.*	Diplograptus palmeus, *Barr.*
—— crassus, *Lapw.*	Peltocaris aptychoides, *Salt.*
—— Hisingeri, *Carr.*	

These *Rastrites-maximus* mudstones pass upwards into a group of massive yellow gritstones very similar, in their petrological characters, to those which succeed to the *M.-Sedgwickii* zone. They resemble these beds most especially in their pale blue matrix, and in containing a notable proportion of calcareous matter, but differ from them in the absence of the fine seams of pebbles and in the total want of organic remains. About 60 feet of these pale yellow gritstones are here exposed, and form the final member of this first or Camregan group, the purple sandstones and shales which follow belonging more naturally to the overlying and succeeding *Crossopodia-* or Purple Shale formation.

Extension of Camregan Beds to the East of Penwhapple Glen.—This marked group of fossiliferous gritstones, calcareous flagstones, and Graptolitiferous shales is traceable up the left side of the stream into the wood of Camregan, where the shell-bearing gritstones are laid open in several quarries near the northern edge of the wood. Here these grits are softer and looser in texture than in the burn itself, and their fossils are procurable with comparative ease. They are crowded with casts of Brachiopoda, which are so abundant in certain seams as irresistibly to recall to mind the wonderfully prolific shelly sandstones of Mulloch Hill, on the north of the Girvan valley. The beds, too, have the same coarse sandy texture, calcareous and gritty composition, and more or less flaggy fracture.

It is this locality which gives its name to the band, as it is the only spot upon its entire course through the Girvan district where it is possible to find a local name geographically significant of the group, and at the same time sufficiently definite in its application to prevent ambiguity. The commonest fossils I have collected here are:—

Rhynchonella llandoveriana.	Tentaculites ornatus.
Atrypa hemisphærica.	Encrinurus punctatus.

I am not able to refer these beds to their exact horizon in the section of the Camregan group as exhibited in the gorge of Penwhapple; but I suspect that they belong generally to the gritty flags with *Rhynchonella*, found in contact with the *Monograptus-Sedgwickii* zone.

In the continuation of the same line of strike to the eastward beyond the limits of the wood we find a small section of the Camregan beds at the head of a small burn running down the hill-slope to the west of the fence. Here only a few flaggy grits and shales are seen; but they contain the usual types of the Camregan limestone, such as:—

Encrinurus punctatus.	Rhynchonella.
Atrypa hemisphærica.	Pentamerus oblongus.

The beds are much shattered, and their relations to the purple mudstones of the succeeding zone to the southward are somewhat obscure, and are in all probability indicative of the presence of a line of fault at the point.

For the next half-mile the beds of the calcareous Camregan zone are obscured by drift and vegetation; but a few yards to the west of the boundary-line between the Killochan and Bargany estates they are exhibited in several small excavations at the head of Cuddystone Burn. These hollows show only the more shaly beds of the series, but these are abundantly fossiliferous. They contain the usual forms of *Rhynchonella*, *Atrypa*, and *Encrinurus*, frequently in an excellent state of preservation.

In the burn-course below, and amid the surrounding patches of heather and long grass, evidences of the presence of the remaining fossiliferous beds of the Camregan group are found in the form of angular blocks of yellow gritstone and fine conglomerate, filled with *Pentamerus oblongus*, and the characteristic hard calcareous flaggy beds, crowded with *Petraia* or *Lindstrœmia*.

This is the final exposure of strata of the Camregan band in this direction, for a few yards to the west it must be cut out by the great Braehill fault; but blocks of the coralline flags and *Pentamerus*-gritstone are found at intervals in the drift down the entire course of Cuddystone Burn, and are frequent in the débris collected off the neighbouring fields.

Sections West of Penwhapple Glen.—From our typical section in Penwhapple Glen the strata of the Camregan grits mount the east cliffs of the glen, and, crossing the Tralorg road, are shown again in the course of the southern arm of the Penkill Burn. Here only a few feet of the calcareous zone and the overlying yellow grits are exposed; but the limestone beds are so convenient of access that they have been long and successfully worked by collectors, and have afforded, especially to the extended and enthusiastic researches of Mrs. Gray, a large suite of fossils of all groups.

In addition to the usual *Pentameri*, Rhynchonellidæ, &c., we find:—

Bronteus Brongniarti, *Barr.*	Strophomena applanata.
Cheirurus trispinosus, *Wyv.-Th.*	—— antiquata.
Encrinurus variolaris, *Brongn.*	Phragmoceras compressum.

and a host of other well-known and typical Silurian forms. Indeed this little spot may well be defined as the typical fossil-bearing exposure of the Camregan Limestone.

For the next two miles the strata of this zone are hidden below the grass-clad surface of the hills; but in the exact continuation of the line of strike we find an excellent exposure of its fossil-bearing shaly beds in a branch of the Bargany Burn, near the western base of the Hadyard Hills. At this spot we discover the shaly strata which occur at the junction of the Camregan Limestone and the fossiliferous zone of purple mudstones.

The grey flaggy shales to the south afford an abundance of casts

of shells of *Atrypa reticularis* and *Strophomena*, and the dark-striped shales to the north well-preserved specimens of

Rastrites maximus, *Carr.*	Monograptus Hisingeri, *Barr.*
Monograptus crassus, *Lapw.*	Diplograptus palmeus, *Barr.*
—— turriculatus, *Barr.*	Peltocaris aptychoides, *Salt.*

Here the strata of this zone make their final appearance in the Girvan region, being buried from sight a few yards to the eastward by the unconformably overlying Old Red Sandstone of Maxwellston Hill.

I regard this Camregan zone, which has formed our chief horizon of reference among the complicated group of Graptolitic shales and flags, conglomerates, gritstones, and calcareous rocks developed in Penwhapple Glen, Saugh Hill, and upon the outer edges of the coast-platform near Woodland, as forming the final member of the *Third Series* of rock-formations into which the Girvan succession is most naturally divided. This series, which commences with the Mulloch-Hill conglomerate, and terminates with the upper grit bands of these Camregan beds, is nowhere completely exhibited from base to summit in continuous section in the Girvan region; and the order of its sediments is only *approximately* determined by the careful piecing together of the disjointed fragments of the sequence found in several scattered localities. Nevertheless I trust that I have shown that, even from the physical point of view, a sufficiency of evidence is at our command to make it clear that the order of succession here adopted is in all probability generally identical with that which obtained among these beds previous to their disruption.

The irregularly scattered distribution of the rocks of this division makes it difficult to suggest a collective title for the whole group that shall be sufficiently comprehensive, and at the same time of definite local value. In the northern inlier in the neighbourhood of the farm of Newlands, the lower half only of the group is exposed. The basal beds, again, are wholly missing from the South Girvan plateau. But the relation of the group as a whole to the underlying formations is best displayed in the Newlands area, within which are also developed all the different lithological varieties of its strata, together with several distinct groups of its fossils. Hence it will be most convenient to distinguish it by the title of the *Newlands Series*.

The strata of this Newlands Series consist of massive beds of shelly sandstones or barren gritstones, occasionally passing into coarse conglomerates and boulder-beds, and alternating with thick zones of grey, green, and black Graptolitic shales.

A striking peculiarity of the coarse beds of this group is their property of weathering to a buff or yellow colour under the action of the weather. In the matter of fossils this group is altogether the most prolific in the Girvan succession.

The order of sequence of the Newlands Series is given in the following scheme, in ascending order:—

Generalized Section of the Newlands Series.

	ft.	
(a) *Mulloch-Hill Group*......	375	1. Mulloch-Hill Conglomerate. 2. Rough-Neuk Grits. 3. Glenwells Shales.
(b) *Saugh-Hill Group*	200	(*a*) Woodland Limestone, Conglomerate, and Shales. (*b*) Saugh-Hill Grits and Flags.
		M.-Sedgwickii *Beds.* 1. Grey Shales, barren of fossils. 2. Black Mudstones with Graptolites.
(c) *Camregan Group*.........	200	1. *Rhynchonella*-Grits. 2. Upper *Pentamerus*-Limestone and Shales. 3. Yellow Gritstones and Flags.

(*b*) *Flagstones and Shales of Bargany and Straiton.*

The Lower Palæozoic strata of the Girvan region which yet remain to be described form a narrow strip of country about ten miles in length, stretching from the banks of Penwhapple Burn, between Penkill and Old Dailly, past the village of New Dailly and the heights of Kilkerran, to the village of Straiton upon the Water of Girvan to the south of Maybole.

Along this line the northern edge of the continuous upland plateau of Saugh Hill and the Hadyard Hills plunges suddenly downwards into the lowlying district of the Girvan valley in a long straight slope of singular steepness. To the west of Penwhapple Glen this steep slope forms a most prominent feature in the landscape, its upper margin presenting a series of rocky points, several exceeding 1000 feet in elevation, which mark the outer edge of the Old Red Sandstone terrace of Garleffin, and its lower portions merging imperceptibly into the maze of parks and woodlands that give such a forest-like aspect to the fertile valley of the Girvan.

The prime cause of this abrupt physical feature is undoubtedly the presence of the great Braehill fault, which runs along the edge of the slope from end to end, throwing down the Carboniferous of the Girvan valley against the Silurian rocks to the south. Throughout the whole of its range this is actually a downthrow to the northward. It is essentially a strike-fault, running almost parallel with the average trend of the Palæozoic rocks, but by no means confined to a single horizon either in the Silurian or the Carboniferous, but truncating the strata of both at a very acute angle.

At its eastern end, within the present district, near Penwhapple, this fault is situated at the base of the steep slope already referred to, and brings into abrupt collocation some of the highest rocks of the Silurian of the Penwhapple, and a zone comparatively high in the Upper Old Red Sandstone. The overlying zones of the Lower Carboniferous emerge one by one till, finally, near the head of Lady Burn, above Kilkerran, the base of the Carboniferous is exposed, and the unconformably underlying Silurian rocks begin

to appear on the northern side of the fault, and they retain this position till we reach the point where the fault passes to the eastward beyond the limits of the region under description. These underlying Silurian strata, being less susceptible of erosion than the neighbouring Carboniferous beds, form the outer edge of the bounding slope of the plateau; and the Braehill fault gradually mounts higher and higher upon the slope as we pass to the eastward till, finally, for the last four miles of its course, near Straiton, it runs almost along the summit.

The band of Silurian rocks found in this district between the Old Red Sandstone of the Hadyard Hills and the Carboniferous of the Girvan valley rarely exceeds half a mile in width; and throughout much of its extent is even less than one fourth of a mile in breadth, while in some spots it seems to vanish altogether. It attains its greatest diameter to the west, along the line of Penwhapple Glen, where its strata are seen following in unbroken sequence upon the yellow *Pentamerus*-gritstones of Camregan and Penkill.

The strata which floor the whole of this narrow band of country consist of thin-bedded flagstones and shales, with seams of hard, but essentially flag-like grits distributed irregularly throughout the succession. If we make exception of the local development of certain brilliant-coloured bands, it may be said that the more prominent petrological characters of these strata are essentially the same everywhere throughout the area; and even upon a first examination the stratigraphist instinctively assigns them all to a single and connected series. From the three rock-series already defined this new series is distinguishable, not only by its petrological characters, but also by the general absence of organic remains, the few fossils it has afforded being restricted to half a dozen widely separated seams, each of a few inches in thickness.

The geographical distribution of this series of grey flagstones and shales admits of being most satisfactorily described, as they present themselves in:—

(1) The lower portion of the gorge of Penwhapple Glen above Old Dailly;
(2) The steep north slope of the Hadyard Hills above New Dailly;
(3) The eastern or Straiton area north of the Bargany fault;

and the entire series is most naturally and conveniently designated by the general title of the *Dailly Series*, after the name of the parish in which its strata are most fully laid open for study, and where they attain their widest geographical extension in the Girvan region.

1. *Section of Lower Portion of Penwhapple Glen* (see fig. 28, p. 645).—The third zone of yellow gritstone, which forms the summit of the *Pentamerus*-bearing Camregan beds of Penwhapple Glen, is at once succeeded by a group of strata altogether more unique in their petrological features than any we have hitherto studied on the banks of the glen. They consist of beds of purple and green shale of great

thickness, the purple strata distinctly predominating, occasionally passing on the one hand into soft mudstones almost destitute of definite lamination, and on the other into flagstones of great thickness. They continue down the stream from the line of *Pentamerus*-gritstone to the final crook of the burn below the farmhouse of Penkill, where they are succeeded by a very distinct group of pale grey flagstones.

The strata lying between these limits must be assigned on petrological grounds to one and the same group or subordinate formation, and will be referred to as the *Penkill Beds*. The section of these beds here displayed appears to be continuous. It is about 500 yards in length, and the total thickness of the strata exposed may be estimated at about 1000 feet.

(Da^1) *Crossopodia Beds or Purple Shales.*—For the first 150 yards the strata of the Penkill Beds consist of finely laminated shales of a deep purple colour, only occasionally interrupted by narrow seams of green or grey. On a few horizons, however, the purple and green shales are arranged in alternating bands of colour of an inch or two in thickness, forming a peculiar striped rock of remarkable appearance. These purple shales are magnificently exposed at this locality, and not only in the bed of the stream itself, but in the steep wooded cliffs on both sides of the gorge; and there is little appearance of contortion or repetition among them.

They are crowded along many horizons with multitudes of worm-tracks and so-called Annelid-trails; in some spots near the southern end of the exposure every lamina is a perfect maze of these imperfectly studied markings. The commonest and most characteristic is M'Coy's *Crossopodia scotica*; and the less conspicuous species are:—

Nemertites tenuis, *M'Coy.*
Nereites Sedgwickii, *M'Coy.*
Nereites cambrensis, *M'Coy.*

Graptolites occur also in the greatest variety in a few seams of slightly carbonaceous shales, discernible with difficulty on several horizons in the succession; they are mere laminæ, and the Graptolites themselves are poorly preserved. The forms collected by myself include:—

Monograptus exiguus, *Nich.*
—— Beckii, *Barr.*
—— galaensis, *Lapw.*
Rastrites distans, *Lapw.*
Diplograptus, sp.
Retiolites obesus, *Lapw.*

(Da^2) *Protovirgularia Flags and Grits.*—These purple shales are succeeded in the section by an equal thickness of flaggy beds of a greyish-green colour, about two inches in thickness, which alternate with green and purple shales, identical with those of the preceding subgroup, and forming a well-marked division of this formation, exactly intermediate in petrological features and geographical position between the purple shales below and the division next to be described. They contain a few of the usual Annelids, together with rare examples of the characteristic *Monograptus exiguus*, Nich., found in a small stream near the northern extremity of the section of these beds.

These flaggy or ribbed shales are followed to the northward by a mass of well-bedded greywackes, which are seen to perfection at the foot of Penkill Burn, below the old castle. Their most southerly beds consist of greywackes from two to three feet in thickness. All the middle and main mass of the zone are flagstones or flaggy greywackes, frequently less than a foot in thickness, with an occasional seam of shale. The final band is a pale grey calcareous greywacke, forming a solid mass several feet in thickness. Fossils are rare. Those known are of the same species of Graptolites as those enumerated from the preceding division; they occur in an insignificant, highly carbonaceous seam overlying the highest greywacke bed.

(Da^3) *Cyrtograptus-Grayi Mudstones*.—The fourth and final division of the Penkill Beds is a mass of soft purple and green mudstones. They are very imperfectly seen in their more southerly beds, between the foot of Penkill Burn and the crook of Penwhapple; but their terminal zone is well exhibited at the latter locality. The purple mudstones are here capped by thin seams of graptolitic and more or less calcareous shales, which are easily studied in the south bank, at the right angle of the burn at this spot, and in the bed of the stream itself at the western angle. The fossils they afford occur in a most exquisite state of preservation, the Graptolites being frequently preserved with their full relief. Here occur

Retiolites Geinitzianus, *Barr.*	Cyrtograptus Grayi, *Lapw.*
Monograptus priodon, *Bronn.*	Cardiola fibrosa, *Sow.*
—— var. Flemingii, *Salt.*	Acidaspis Brightii, &c., *Murch.*

together with a few examples of Brachiopoda and Crustacea.

The remaining rocks of this locality belong to the distinct Bargany beds, and will be noticed in detail when we come to speak of the strata to the eastward.

This completes the description of the Purple-shale and Flagstone group as seen in Penwhapple Glen. The section here must be regarded as typical. The old castle of Penkill, the seat of the Boyd family, is built upon these rocks, above the cliffs of Penwhapple, about the centre of the group. It is therefore entitled the Penkill group, and is regarded as being composed of the following divisions:—

Penkill (*Crossopodia*-) Group.	(4) Penkill mudstones or *Priodon* (*Grayi*)-beds.	
	(3) Penkill greywackes.	*Protovirgularia*-beds.
	(2) Penkill flags.	
	(1) Penkill or Purple shales (*Crossopodia*-beds).	

Geographical Extension of the Penkill Beds.—The broad band of purple and grey strata formed by the beds of the Penkill group is traceable for some distance both east and west of the typical section in Penwhapple Glen. A tolerably continuous section across many of the beds of the group is seen in the course of the small burns which descend the northern slope of Camregan Hill, immediately west of the plantation, while scattered exposures are seen in occasional quarries in the wood itself. In all these localities we find an abundance of the characteristic Annelid-trails &c.

On the east of the glen, the little stream which crosses the line of the Camregan limestone upon the Assel road, and falls into the Penwhapple below Penkill Castle, affords an excellent confirmatory section of the *Crossopodia*-shales. Some of the beds of the higher greywacke zone are laid open in quarries about half a mile north-east of the Castle, where those beds present identical characters with their counterparts in Penwhapple, and afford a few examples of Annelid-trails and the enigmatical fossil *Protovirgularia*.

The Burn of Bargany, yet further to the east, crosses the band almost at right angles to its course; but only a few poor sections are exposed along it. Such as these are, however, they are sufficient to prove that the group retains the same sequence and thickness as in our typical section.

A few yards west of this burn these strata are unconformably overlain by the Old Red Sandstone beds of the Maxwellston Hills.

2. *Sections south of Bargany.*—The sections we have next to notice are found in the steep slopes which overlook the beautifully wooded lands of Bargany House, and occur at scattered intervals in that long strip of Silurian lying between Penwhapple Glen and the Burn of Lindsay's town, about four miles to the eastward. The rocks which occupy this subarea are all very similar in their external features, consisting of (*a*) grey and green flagstones and occasional greywackes, with dividing seams of shales, and (*b*) thick zones of ribbed shales, arranged in alternating hard and soft bands of an inch or two in thickness. They all dip, as a rule, at a steep angle to the southward, as if passing below the zone of the Penkill shales last described; but here, as in Penwhapple Glen, this apparent dip is delusive, the strata being inverted in geological position.

Near the foot of Penwhapple Glen the most southerly beds of the Bargany flagstones are seen in the bed and banks of the stream, succeeding and apparently overlying the fossiliferous "*Cyrtograptus-Grayi* band" with perfect regularity. They consist of grey flags varying from six inches to a foot and half in thickness, and are divided from each other by similar thicknesses of grey and green shales. When split open, the matrix of the generality of the beds is seen to be finely levigated and of a peculiar palish blue or greyish-green tint, a feature which distinguishes more or less all the beds seen in the Bargany area. The harder flags are frequently filled with closely approximately transverse fractures and joints, which allows of their weathering into a multitude of long angular prisms, the outer ends of which are concident with the base and summit of the flaggy bed out of which they are formed. These beds fill up the final 300 yards of space which intervene between the *C.-Grayi* band and the great Bargany fault to the north, where the Lower Palæozoic rocks are brought into contact with the greenish-grey sandstones of the Old Red Sandstone of the Girvan valley. These Bargany flags are here totally barren; their visible thickness may be estimated at 300 feet.

A tolerably continuous section of the same flaggy series is seen in the course of Bargany Burn, about a mile and half to the eastward

of this spot. The purple mudstones of the "*C.-Grayi* bed" which caps the Penkill-shale group of that locality are succeeded to the northward by scattered exposures of pale jointed flagstone with shale-partings, identical with the flagstones of Penwhapple Glen-foot. These Glenfoot flags extend down the stream for a distance of about 200 yards, and agree therefore in collective thickness with their counterparts of the glen.

Between them and the great Bargany fault to the northward, which is shown in a section of great interest in Blackwood Head coppice, is found an equal thickness of grey, flaggy shales or muddy flagstones. Many of these have the same pale-coloured interior as the Glenfoot beds; but they are altogether a more finely laminated group, showing no actual greywacke zones at this spot, but only occasional harder ribs. They are beautifully shown in the cliffs of the little glen dug out by the burn, at the waterfall near the Bargany fault, where they are seen in contact with the Carboniferous of the Girvan valley. They are frequently striped with faint lines of carbonaceous matter, suggestive of the presence of Graptolites, a few of which are obtainable at this spot, such as

Monograptus acus, *Lapw.*	Monograptus priodon, *Bronn.*

The next stream-course to the eastward, which excavates a small gorge on the opposite side of the wood, presents us with a section of parts of the Glenfoot flags and these shalier Blackwood-Head beds. The Glenfoot beds exposed are especially interesting, as they are higher in the group than the majority of those we have studied in Penwhapple Glen. The final band is seen to contain several seams of sandy greywacke of a pale purplish colour, while the intermediate shales have a peculiar greyish-green or, as it were, washed-out tint, and a dull flaky surface, which is new among the beds hitherto met with in the Girvan succession.

The lowest ribbed shales of the Blackwood-Head beds are shown in two fine quarries, and form a most conspicuous assemblage of about 150 feet of dull greyish-brown rocks in beds of about 2 inches in thickness.

A few feet of the higher striped shales are seen to the northward, close to the line of fault.

In the small hollow of the Lime Glen, three fourths of a mile further to the eastward, the pale-hearted finely levigated sandstone flags of Blackwood-Head occur in a broken section in the neighbourhood of the Bargany fault. So far as can be made out upon the ground, they here consist of three distinct lithological seams, viz.

(*c*) Yellow-weathering mudstone flags, pale-hearted, white or bluish grey.

(*b*) Yellow-weathering mudstone flags with stripes of carbonaceous matter.

(*a*) Pale-green ribbed shales and mudstones.

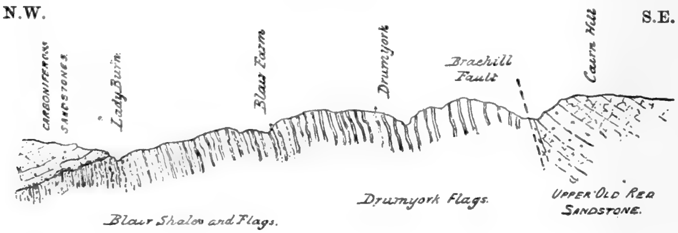
The white-hearted mudstone flags (*c*) are seen also in Currah Glen. In some neglected quarries below the rugged cliff to the south-west

of the farm-house of Craig, fine greenish-grey shales are exposed, not unlike those of the quarries east of Blackwood Head; but the latter lie at the northern limits of the Blackwood beds, while these Craig shales, if the strike of the beds is to be trusted, lie on the opposite or southern side of the band.

No further exposure of any moment is seen in this direction till we cross the supposed line of the Braehill fault on the Bargany Hill, and enter upon the Straiton band of Silurian strata, which, near Blair Farm, emerges from below the Carboniferous rocks of that district.

3. *Blair Farm and Drumyork.*—The Silurian strata are laid open in many sections in the course of the Lady Burn above Kilkerran House, near Drumyork, and in the grassy mounds around the farmhouse of Blair. The disposition of the strata at this locality will be evident on a study of the accompanying section (fig. 29).

Fig. 29.—*Section of the Grey Flags and Shales of Blair and Drumyork.*



D. Dailly Series.
Db. Straiton beds.
(*b*) Blair shales and flags, with *Cardiola, Ceratiocaris, Retiolites,* and *Monograptus vomerinus.*
(*a*) Drumyork flags, olive-green, non-fossiliferous.

What are considered to be the lowest beds are seen in the stream-course close to the Bargany fault above Drumyork. They consist of olive-green flags and shales, much jointed and contorted, crushed abruptly against the Old Red Sandstone rocks to the south.

These beds are succeeded by flaggy shales with occasional ribs of flagstone, weathering often of a dull yellowish tint, some striped with lines of carbonaceous shales, others of a cold olive-green colour, more or less calcareous, and with rough harsh flaky surface. These are exhibited in many natural and artificial openings on the south side of the hill-road between Drumyork and Blair Farm. In a quarry about a hundred yards east of the farmsteading they afford in great abundance the characteristic fossil *Monograptus vomerinus*, Nich., and less commonly the following species:—

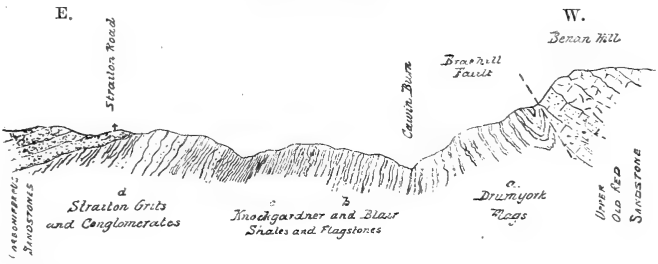
Beyrichia Klœdeni, *M'Coy.*	Cardiola fibrosa, *Sow.*
Orthoceras subundulatum, *Portl.*	Bellerophon wenlockensis, *Sow.*
Retiolites Geinitzianus, *Barr.*	Cyrtograptus, sp.

Between these beds and the southern margin of the overlapping strata of the Lower Carboniferous to the north, beds of flagstone, varying from a foot to a few inches in thickness, and separated by seams of striped blue and grey shales, are seen at several spots in the Lady Burn; they are occasionally fossiliferous, affording

Cyrtoceras, sp.	Monograptus vomerinus, *Nich.*
Orthoceras subundulatum, *Portl.*	—— Flemingii, *Salt.*

It is doubtful if any of these beds actually belong to the Bargany group of the area last described, though they greatly remind us of the strata of that group in their general features. They clearly belong both physically and geologically, however, to the same general series as the Bargany beds, possibly following them in the natural order of succession.

Fig. 30.—*General Section of the Silurian beds of Knockgardner and Straiton.*



D. Dailly Series.
Db. Straiton beds.
(*d*) Straiton purplish conglomerate, grits, and flags.
(*c*) Thin-bedded shaly flags, with *Beyrichia Klœdeni* (Knockgardner beds).
(*b*) Grey flags and shales (Blair beds).
(*a*) Olive-coloured, non-fossiliferous flags and shales (Drumyork flags).

4. *Knockgardner and Straiton* (fig. 30).—The flaggy strata of the three subzones of the Blair beds range from this point eastward to the village of Straiton, a distance of at least $3\frac{1}{2}$ miles, running strictly parallel with the Bargany fault to the southward. In the course of a small stream descending the north slope of Benan Hill, a mile south-west of Straiton, the cold olive-green flags of Drumyork are again seen in contact with the Old Red Sandstone. The more finely laminated strata of Blair Farm are exposed in quarries at the farmsteading of Knockgardner, where they are crowded with *Beyrichia Klœdeni*, M'Coy, and yield a few scattered examples of characteristic Blair fossils, *Pterinea pleuroptera*, Conr., *Orthonota truncata*, Conr., &c., and indeterminate species of *Cyrtograptus* and *Monograptus*.

The same beds are seen further east in the banks of the Cawin Burn. Of the most northerly or highest (?) zone of the Blair beds, only a short section is seen in the streams running down the peaty region north of Shaw's Knowes.

West of the village of Straiton the terminal beds of this flaggy zone are succeeded in the hillocks south of the roadside by a most peculiar set of strata, consisting of purple and grey conglomeratic greywacke and flagstone, of great hardness and toughness. The matrix of the chief grit or conglomerate band is purple, and is more or less sandy in character, reminding us of the red conglomerate at the base of the Mulloch-Hill Sandstone. It is interbedded with blue mudstones and olive-green flaggy shales. These beds are all wholly destitute of fossils, but form together a most distinctive physical assemblage.

The same zone of purple flagstone and conglomerate is found in precisely the same stratigraphical position along the line of strike two miles to the westward, where it is shown in some old quarries near the roadway between Knockgardner and Kirkbride.

At both these localities this Straiton gritstone band is followed unconformably by the overlying Carboniferous rocks of the Girvan valley, thus forming the outer and final member of the entire Lower Palæozoic series of this region. To the west of Straiton itself the southern margin of the Carboniferous rocks creeps down upon the Bargany fault, and the Silurian is finally buried from sight by the unconformably overlying strata of Upper Palæozoic age.

It is evident from the foregoing descriptions that the whole of the strata found in the long strip of Silurian country extending from the Braehill near Girvan to the village of Straiton, and forming the northern slope of the plateau lying to the south of Girvan valley, belong to one and the same general physical series. To this series, which we term the Dailly Series, after the parish in which its strata are most perfectly developed in this region, must clearly be assigned the highest place among the four natural divisions of the Girvan succession, for it follows the third or Newlands division in the geographical order of the deposits of the region, and graduates therefrom in its lithological characters. Its strata dip either perpendicularly or at steep angles to the southward, as if to pass under this third or Newlands series. But not only is their superiority in stratigraphical position to be inferred from the fact already demonstrated that the strata north of the Knockgerran fault are generally inverted, but it is placed wholly beyond question by the evidence of the fossils. This inversion, then, being admitted for the series as a whole, it is to be expected that there is actually to be found an ascending order among the beds as we depart northward from the Camregan grits, which form the highest band of the Saugh-Hill series in the direction of the Bargany fault and the unconformably overlying Carboniferous. We have seen that there can be no dislocation of importance in any of the sections capable of study, the beds following each other with great regularity in parallel zones, which graduate almost insensibly the one into the other. Reserving therefore the palæontological arguments in support of these views to the succeeding part of this memoir, we are justified in the presumption that the Dailly Series consists of the following groups in descending order :—

Generalized Section of the Dailly Series.

Dailly Series, 2600 feet.	Upper Dailly.	Straiton beds, 900 ft.	Straiton Grits and Conglomerate. Blair Shales (*Vomerinus*-beds). Drumyork olive-coloured Flags.
		Bargany beds, 700 ft.	Blackwood Flags. Glenfoot Flags and Shales.
	Lower Dailly.	Penkill beds, 1000 ft.	*Cyrtograptus-Grayi* mudstones. Penkill Greywackes. *Protovirgularia*-flags. *Crossopodia*- or Purple Shales.

(F) Summary of the foregoing Evidences and Conclusions respecting the Stratigraphy of the Girvan Succession.

(1) In the foregoing pages I have laid before the reader all the more important data obtainable in the geographical area under examination which bear upon the main question of the natural order of the Lower Palæozoic rocks of the Girvan region. The original arrangement of the beds themselves has been so frequently interrupted by profound dislocations, and has been rendered so dubious locally by perplexing folds and inversions, that the task of reducing them to their natural order has been one of far more than ordinary difficulty. But so well are the several subformations in the collective series individualized by distinct petrological features, that the field-geologist has generally little hesitation in recognizing their entangled or dislocated fragments at a glance. At the same time also the foldings and inversions of the strata prevail only in certain definite geographical subareas, where they can usually be ultimately detected and allowed for. Finally, the greater faults are, as a rule, by no means difficult of localization, owing to the fact that they bring into abrupt and unnatural collocation upon the ground strata very distinct in their lithological and palæontological features.

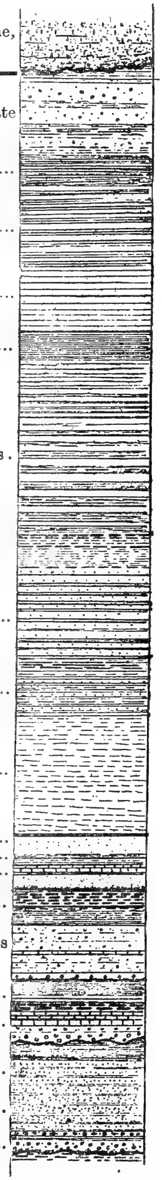
Nevertheless the complexities and difficulties of the stratigraphy of the fossiliferous rocks of the Girvan region are so great that the solution of the problem of their natural sequence has been only arrived at by the accumulation of an excessive amount of evidence collected in the field. This evidence, however, is now so full, and so conclusive, that there can be no longer any doubt of the natural petrological subdivisions of the strata of the Girvan rocks, or of their true positions in the ascending succession.

(2) The physical evidence, as developed in the preceding pages, in support of our conclusions may be summarized as follows:—

(i) Selecting the remarkable Benan-Hill Conglomerate as our primary horizon of reference, we discover that it is merely the central member of a series (the *Barr Series*) of boulder-beds and conglomerates, with intercalary zones of limestone and fossiliferous shales. This series exhibits proofs of the most perfect conformity from base to summit, and its various members admit of minute and

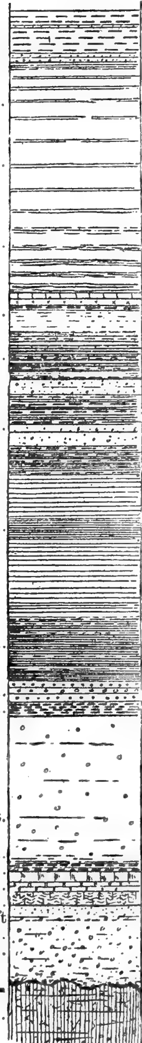
Fig. 31.—*Detailed Vertical Section of the Strata of the Girvan Succession.*

(Scale 1 inch=480 feet.)



Upper Palæozoic rocks, Old Red Sandstone, and Carboniferous	
UPPER GIRVAN ROCKS.	
(D) DAILLY SERIES, 2600 ft.	
(*c*) STRAITON GROUP, 900 ft.	
4. Straiton grits and conglomerate	Coarse purple and grey grits and conglomerates, non-fossiliferous.
3. Knockgardner shales	Flaggy shales, with *Beyrichia Klœdeni* &c.
2. Blair flags and shales	Grey flags and pale green flaky shales.—*Monograptus vomerinus, Cardiola,* &c.
1. Drumyork flagstones	Olive-green flags and shales, non-fossiliferous.
(*b*) BARGANY GROUP, 700 ft.	
2. Blackwood beds	Pale yellow and blue and grey flagstones, with thick zones of pale green and ribbed shales.—*Monograptus acus* &c.
1. Glenfoot pale flags and shales	Pale blue and grey thick-bedded flagstones, with many zones of pale grey and buff weathering shale.
(*a*) PENKILL GROUP, 1000 ft.	
4. *Cyrtograptus-Grayi* mudstone.	Purple mudstones, with calcareous seams.—*Monograptus priodon, Cyrtograptus Grayi, Retiolites Geinitzianus,* &c.
3. *Protovirgularia*-grits	Thick-bedded green and grey grits, with Annelides and *Protovirgularia, Monograptus galaensis.*
2. Penkill flags and shales	Alternations of grey and green flagstones and shales.—*Monograptus exiguus.*
1. *Crossopodia*-shales	Purple shales and mudstones, with *Crossopodia scotica, Nemertites tenuis,* &c.
(C) NEWLANDS SERIES, 1050 ft.	
(*c*) CAMREGAN GROUP, 200 ft.	
3. *Rastrites-maximus* shales 2. Camregan limestone 1. *Rhynchonella*-grits	Thick-bedded yellow grits, purple and grey mudstones, and a band of impure limestone.—*Rastrites maximus, Pentamerus oblongus,* &c.
(*b*) SAUGH-HILL GROUP, 500 ft.	
(*c*) *Monograptus-Sedgwickii* beds	Black carbonaceous mudstones, with *Monograptus Sedgwickii, Rastrites maximus,* &c.
(*b*) Saugh-Hill sandstones and grits	Coarse yellow flaggy sandstones, quartz conglomerates, and pale grey flags.
(*a*) Woodland Beds.	
(*c*) *Modestus*-shales (*b*) Woodland limestone (*a*) Craigskelly conglomerate	Black and striped Graptolitic shales, with *Diplograptus modestus*; limestone with *Stricklandinia lens*; and zone of boulder-conglomerate.
(*a*) MULLOCH-HILL GROUP, 350 ft.	
3. Glenwells pale shales	Pale blue shales and mudstones, with *Ptilograptus.*
2. Mulloch-Hill sandstone	Red, grey, and yellow sandstones, with partings of sandy shales, crowded with Brachiopoda, *Meristella angustifrons, Atrypa hemisphærica,* &c.
1. Mulloch-Hill conglomerate	Purple boulder-conglomerate.

Fig. 31 (*continued*).



LOWER GIRVAN ROCKS.

Series	Group	Description
(B) ARDMILLAN SERIES, 2500 ft.	(*d*) DRUMMUCK GROUP, 200 ft.	Dark grey mudstones, with occasional flaggy bands, with *Trinucleus Bucklandi, Ampyx rostratus.*
	(*c*) BARREN FLAGSTONES, 800 ft.	
	(*c*) Upper beds	Thick-bedded pale flags, with intermediary bands of buff-weathering shales.—*Dipl. truncatus.*
	(*b*) Middle beds	Thick-bedded grey flagstones, with partings of green and grey shales. No fossils.
	(*a*) Lower beds	Green shales, with occasional flaggy bands.—*Nematolites,* sp.
	(*b*) WHITEHOUSE GROUP, 300 ft.	
	(*b*) Variegated mudstones	Red mudstones, grey, green, and black shales. *Dionide, Ampyx, Asaphus, Æglina, Dicell. complanatus,* &c.
	(*a*) Cement-stone Group	Striped grey shales and mudstones, with cement-bands. —*Leptograptus flaccidus,* Brachiopoda.
	(*a*) ARDWELL GROUP, 1200 ft.	
	3. Cascade-grits and shales	Coarse grits, with thick zones of striped shales.—*Dicellograptus Forchhammeri, Climac. caudatus.*
	2. Middle Ardwell beds	Zones of hard, dark, slaty flags, with seams and bands of dark flaggy shales.—*Dicranograptus ramosus, Diplograptus rugosus.*
	1 Knockgerran shales	Dark carbonaceous and pyritous shales, with occasional cement-bands.—*Cryptograptus tricornis, Climacograptus Scharenbergi.*
(A) BARR SERIES, 850 ft.	(*d*) BALCLATCHIE BEDS, 100 ft.	
	(*b*) Grits and conglomerate	Ashy grits and boulder-conglomerate, with thick zone of nodular green shales, highly fossiliferous.
	(*a*) Fossiliferous mudstones	
	(*c*) BENAN CONGLOMERATE, 500 ft.	Coarse boulder-conglomerate; matrix sandy or gritty; colour usually green or grey.
	(*b*) STINCHAR LIMESTONE GROUP, 150 ft.	
	4. *Didymograptus*-shales	Calcareous and nodular shales.—*Didymograptus superstes, Dicellograptus sextans.*
	3. Compact limestones	Hard compact flaggy limestone, non-fossiliferous.
	2. *Maclurea*-beds	Nodular limestones, with *Maclurea Logani.*
	1. *Orthis-confinis* beds	Impure calcareous beds, with *Orthis confinis* &c.
	(*a*) KIRKLAND CONGLOMERATE, 100 ft.	
	2. Transitional sandstones	Purple and grey sandstones and grits.
	1. Purple boulder-conglomerate	Boulder-conglomerate; matrix usually calcareous; colour purple, red, or white.
	BALLANTRAE ROCKS	

complete investigation in the field. This Barr Series includes the well-known Craighead or Stinchar Limestone as a subordinate member near its base, where it is divided from the underlying Ballantrae rocks by a calcareous conglomerate and breccia of irregular thickness.

(ii) The tumultuous Barr Series is everywhere conformably surmounted, in the sections of the Girvan region, by a second series (the *Ardmillan Series*), composed throughout of Graptolitic flagstones and shales, which nevertheless arrange themselves naturally in several distinct subformations of well-marked petrological characters. The higher and lower divisions of this great series (the Ardwell, Barren Flagstone, and Drummuck Beds) have their respective systematic positions fixed by incontestible stratigraphical evidences. The proper relations of its central divisions (the Cascade and Whitehouse beds), the strata of which are usually inverted, are established mainly by geographical considerations.

(iii) The Graptolitic series of Ardmillan visibly underlies a third series (the *Newlands Series*), consisting of *Brachiopod*-sandstones, *Pentamerus*-grits, and *Monograptus*-shales. The natural place of the first (Mulloch-Hill beds) division of this series is fixed beyond dispute by its relation to the terminal beds of the older Ardmillan series, and that of the highest division (the *Camregan* group) by its relation to the newer *Dailly Series*. The systematic position of the central division (the Saugh-Hill group) is deduced with equal certainty from its intermediary place in the series; but the sequence of the component strata of this central division is rendered so dubious by inversion, faulting, and local unconformities, that we are unable to give more than a provisional classification of its minor zones.

(iv) Finally, we discern a fourth petrological series (the *Dailly Series*), at once the thickest and most homogeneous series in the Girvan succession. Its place at the summit of the whole is established by the circumstances that it forms a single series of similar strata, which is wholly distinct from either of the series below, while it lies on the southern (or upper) side of the Newlands Series, from the highest zones of which its strata appear to graduate in conformable sequence.

(3) In place of an enigmatical group of Lower Palæozoic rocks of no great vertical thickness, varying locally in their petrological characters to an extraordinary extent, and containing an admixture of fossils elsewhere characteristic of formations of several distinct geological epochs, as believed by some of the earlier students of these beds, we find an orderly arranged sequence of strata several thousands of feet in vertical thickness, grouped very naturally in successive formations of distinct petrological features, each formation retaining even in its subordinate zones the same characters over the entire area, and, as we shall show in the second part of this memoir, invariably affording the same special group of fossils.

(4) In brief, our study of the stratigraphical relations of the rocks of the Girvan succession has fully established the following propositions:—

i. The Girvan succession of Lower Palæozoic rocks consists of a generally continuous series of more or less fossiliferous strata of a collective thickness of 7000 feet.

ii. It is divisible into four main rock-formations, each of which is individualized by special petrological and palæontological characteristics.

iii. Each of these formations is, again, made up of several subordinate members, whose relations to the subformations above and below are beyond dispute, and which retain their special characteristics both in rocks and fossils wherever they are laid open for investigation within the district.

The detailed classification of these Lower Palæozoic strata of Girvan, as developed in the preceding pages, is given in the Table, fig. 31, pp. 660, 661.

(5) These Girvan rocks appear to repose, at their base, upon the generally older igneous and altered rocks of Ballantrae. The Ballantrae rocks have, as yet, been too imperfectly studied to allow us to hazard any conclusion respecting their true geological age. That many of the rocks grouped together under this title are of far greater antiquity than the basement-beds of the Girvan succession may be regarded as established by the fact that fragments of the Ballantrae rocks occur in the Kirkland or Purple Conglomerate at the base of the Girvan sequence. These pre-Girvan traps and ashes must either represent the Arenig and Llandeilo volcanic rocks of Wales and Cumberland or must be of more ancient date. On the other hand, rocks which are unquestionably of true Girvan age occur at many localities within the typical Ballantrae region itself, while the patches of altered or so-called Ballantrae rocks found outside that area, as at Shalloch Hill, Laggan Hill, and elsewhere, almost certainly include some greatly altered Girvan rocks.

(6) The sequence among the Girvan fossiliferous rocks is broken by at least one fairly distinct unconformability, viz. that at the base of the Craigskelly conglomerate; but the presence of boulder-beds at the base of the Mulloch-Hill group, at the base of the Saugh-Hill Grits, and elsewhere, renders it exceedingly probable that other local stratigraphical breaks may eventually be detected.

These local unconformities, however, can be of no great systematic importance; for the general gradation, both in sediments and fossils, from the base to the summit of the Girvan succession is practically complete. Each distinct petrological formation in the vertical series is connected with its neighbours, both above and below, by a group of beds intermediate both in physical and in zoological features. Thus the very distinct formations of the Stinchar Limestone and the Benan Conglomerate graduate into each other through the transitional zone of the *Didymograptus*-beds (Ab^4), the Benan and Ardwell series through the transitional Balclatchie group, the Ardwell and Whitehouse beds through the intermediary Cascade beds, and so on. Even the two grand divisions of the succession, the Upper and Lower divisions of the Girvan rocks, are united by the intermediary formation of the Mulloch-Hill beds.

The geographical distribution of the various members of the Girvan succession within the region we have described is given in the accompanying Maps and Plates, &c.

The detailed description of the physical structure of the region, and of the lithology and palæontology of the several members of the Girvan succession, together with the discussion of their resemblances, physical and zoological, to their extra-Girvan equivalents, are points deferred to the second part of this memoir.

EXPLANATION OF THE PLATES.

Plate XXIV.

General Map of the Girvan District.

Plate XXV.

Maps of the more important subareas of the Girvan District.

Map 1. The Saugh-Hill and Penwhapple district.
2. The Stinchar and Benan-Hill district.
3. The coast-line from Ardwell to Shalloch Forge.
4. The Quarrel-Hill and Newlands district.

Discussion.

Dr. Davidson said that though he had not visited the locality, Mrs. Gray's fine collection of Girvan fossils had lately passed through his hands, and Prof. Lapworth had supplied him with his classification of the rocks. He had examined the fossils carefully, and compared them with the table of strata made from Prof. Lapworth's notes, and found them to coincide in every particular.

After about four months of assiduous research he was able to recognize, from the Llandovery, Caradoc, and Upper Llandeilo of that district, some 115 species, an enormous number from so restricted a locality. Some of the forms are quite new, and have not been hitherto discovered either in England or in Ireland.

It was astonishing to find so very large a number of species in rocks attributed to the Upper Llandeilo in Scotland; for whilst in England and in Ireland the total number of recorded species of Brachiopoda from the whole of the Llandeilo would not exceed some 28, the Upper Llandeilo of Ayrshire alone has furnished us with nearly 60. Of this number about 18 would be common to the Llandeilo of England (including Ireland) and Girvan; so that, with the exception of about 10 species, all the others would be, in the present state of our knowledge, peculiar to Scotland. Of course these numbers are provisional, as Dr. Davidson had not finally completed his investigations, but the general results will not be materially modified. On the other hand, whilst some 75 species have been recorded from the Caradoc of England and Ireland, only about 28 have been collected from the Middle and Upper Caradoc of Girvan. Nearly all the Caradoc species found in Ayrshire occur

also in our English rocks of that age; and some more have been found in Peeblesshire, the Lead-Hill district, and in some other places in Scotland, which will swell out the list of Scottish Caradoc forms. Endeavouring to ascertain, as nearly as possible, how many species of Caradoc Brachiopoda occur in the Upper Llandeilo of Scotland, Dr. Davidson found that about 30, or a little more than half, of the Upper Llandeilo species passed upwards into the Caradoc, or were common to both periods.

With respect to the Llandovery, which Prof. Lapworth divides into Lower, Middle, and Upper, he found 15 species in the lower division, 29 in the middle, and 34 in the upper. Of these, 6 are common to the three divisions, 14 to the middle and upper divisions, 10 pass from the Caradoc into the Llandovery, and 4 species only seem to have passed upwards through the whole Girvan series, viz. *Orthis calligramma*, *O. elegantula*, *Strophomena rhomboidalis*, and *S. corrugatella*. Thirty of the Llandovery species occur likewise in the Wenlock and Ludlow rocks. There is therefore a very marked difference between the species of Brachiopoda that characterize the Upper and Lower Silurian rocks of Great Britain.

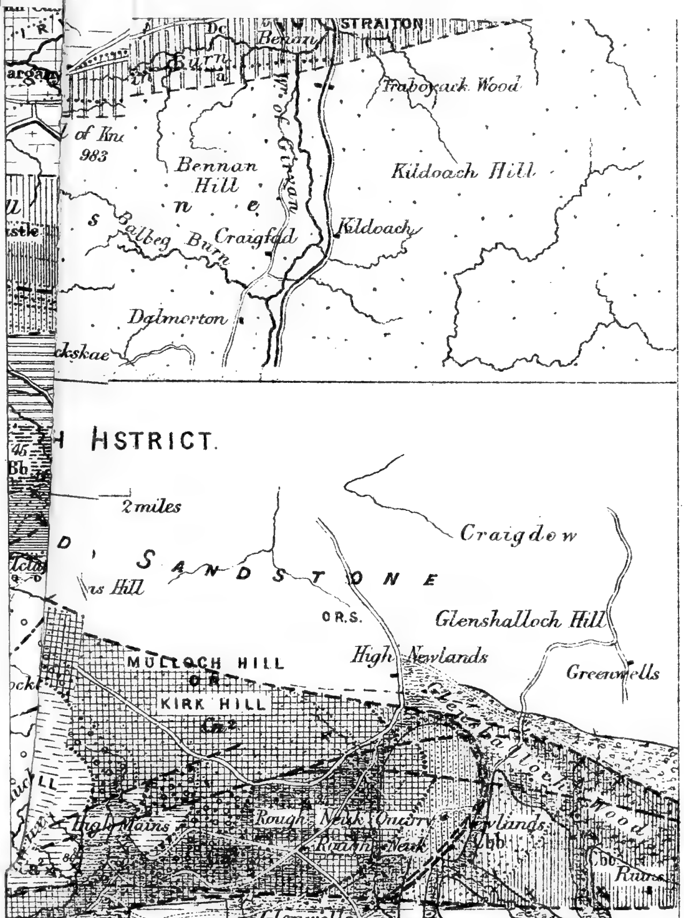
Dr. Hicks said the paper showed how we were gradually being able to correlate the various districts of the Lower Palæozoic rocks, and arriving at a tolerably universal order in the succession. It was impossible to touch upon all the important questions raised by this paper. Among them he would, however, notice one or two. The paper showed that in one direction there were shore-lines, and in another there were deeper waters—a point of great importance in physical geology. He also noticed in Prof. Lapworth's map, in one corner, an area of metamorphic rocks overlain by conglomerates, and probably of Precambrian age. This would have an important bearing on the question of the age of the beds in the north of a similar character, but supposed by Murchison and the Survey to be of Silurian age. Here also we find the newer beds, as there, frequently faulted down among the older ones. We were greatly indebted to Prof. Lapworth for the admirable work he had done.

Prof. Hughes agreed with the conclusions of Prof. Lapworth, and pointed out that in Wales and England we had the same order of succession of the life-zones so far as they had been worked out. In North Wales the Llandeilo beds were not well defined, being near the volcanic centre; in South Wales they were more fossiliferous, but were soon overlapped. The great difficulty in correlation was in the May-Hill series (Upper and Lower Llandovery), in which we had variable basement beds, indicating the submergence of an irregular land surface. At Llandovery there was a great thickness of both Upper and Lower divisions, with the zone of *Stricklandinia lens* and *Meristella crassa* in the Lower, and of *Pentamerus oblongus* in the Upper. On the west flanks of the Malvern range, within the area mapped as Hollybush Sandstone, he had found May-Hill beds below the zone of *P. oblongus*. In North Wales and the Lake-district there is no clear equivalent of the Upper May-Hill; but a variable basement series can be traced having palæontological affinities with

the Lower May-Hill. On either side of the Lake-district (at Rebecca Hill, Ireleth, and at the west end of the Craven district) a conglomeratic base marks the horizon of a break corresponding to that described by Prof. Lapworth at the base of his Upper series.

Mr. Etheridge expressed his high opinion of the work done by Prof. Lapworth. It was most satisfactory to thus see how important palæontological evidence became in unravelling a difficult country. The mistake of not paying sufficient attention to palæontology had, he thought, been made in mapping the northern part of Britain. He believed that Prof. Lapworth had successfully unravelled this difficult region; and we should be thankful to him for the unwearied labour and the patience and knowledge he had brought to bear upon it.

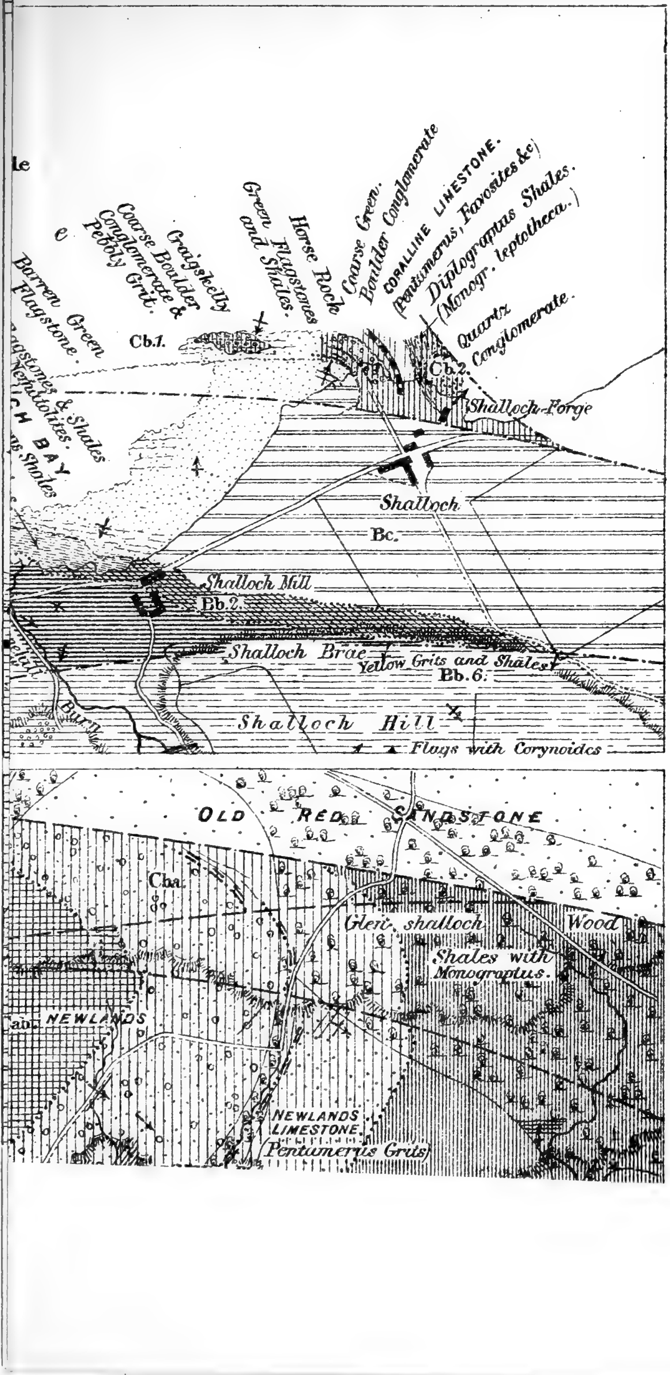
Prof. Lapworth, in reply, thanked the Meeting for the reception it had given him. In the present part of his paper he had dwelt mainly on stratigraphical arguments; but, as regards the second part, he must express his gratitude to Dr. Davidson for what he had done in aiding him. He had also said little about Mrs. Gray's collection, as that was in process of being described, and would be treated in detail in the succeeding portion of the memoir. As regards the older rocks mentioned by Dr. Hicks he said little, as it was foreign to his paper; but the Ballantrae rocks were certainly older than the Girvan beds, as fragments of them occurred in conglomerates at the base of the Girvan rocks, and the latter overlie them. With regard to the basement beds of the Llandovery in North Wales, he had examined them and believed there were three series, as in Scotland,—one only near Birmingham, two as you approached the Stiper Stones, and a third in the Welshpool area; so that he was in favour of putting all the Llandovery beds into the Silurian. He thanked Mr. Etheridge for his support, and would call attention to the valuable work done by Mr. Etheridge, Jun., on the fossils from this locality. He called attention to the way in which his own work bore out Dr. Smith's dictum of "strata identified by superposition and organic remains."



STRAITON
Benan
Burn
Traboyack Wood
of Kn
983
Bennan Hill
Kildoach Hill
Balbeg Burn
Craigfad
Kildoach
Dalmorton
ckskae
H HSTRICT.
2 miles
D SANDSTONE
Craigdow
ns Hill
O.R.S.
Glenshalloch Hill
MULLOCH HILL OR KIRK HILL
High Newlands
Greenwells
Glenshalloch Wood
High Mains
Rough Neuk Quarry
Newlands
Roughneuk
Glenwells
Drummochreen
LIMESTONE
Pathhead
Wallace Town
Dalquharran
moddie T.P.
Dalquharran Park
Fredk Dangerfield Lith. London

Chas. Lapworth Delt.

Fredk Dangerfield Lith. London


Craigskelly
Coarse Boulder
Conglomerate &
Pebbly Grit.
Green Flagstones
and Shales.
Horse Rock
Coarse Green.
Boulder Conglomerate
CORALLINE LIMESTONE.
(Pentamerus, Favosites &c)
Diplograptus Shales.
(Monogr. leptotheca.)
Quartz
Conglomerate.
Barren Green
Flagstone.
Cb.1.
Cb.2.
Shalloch-Forge
Shalloch
Bc.
Shalloch Mill
Pb.2.
Shalloch Brae
Yellow Grits and Shales
Pb.6.
Shalloch Hill
Flags with Corynoides
OLD RED SANDSTONE
Cba.
Glen shalloch
Wood
Shales with
Monograptus.
NEWLANDS
NEWLANDS
LIMESTONE.
(Pentamerus Grits)

MAPS OF THE CHIEF SUB-DISTRICTS OF THE GIRVAN REGION.

Chas. Lapworth. Delt.

Fredk Dangerfield Lith. London. 4520

50. *The* NEWER PLIOCENE PERIOD *in* ENGLAND. By SEARLES V. WOOD, Esq., F.G.S. (Read May 24, 1882.)

[Continuation of Part I. from Vol. xxxvi. of the Journal, p. 527.]

[PLATE XXVI.]

IN the previous part of this Memoir, after describing the conditions under which the beds of the Red and Fluvio-marine Crag accumulated, and their overspread during a depression by the Chillesford Clay, I traced the progress of events from this time to the recession of the ice of the Major Glaciation, in the following order, viz.:—

The elevation and denudation of much of this Crag and Clay over all but their north-western, or most estuarine, extremity, and the formation at Kessingland, in North-east Suffolk, of a freshwater bed on one of the islands which came into existence by such elevation and denudation.

The setting-in of the great submergence, the commencement of which carried the sea over the valley in which the river that flowed into the estuary of the Fluvio-marine Crag had run, represented by the chalk floor extending from Weybourn to Hasboro', and the progress of which was accompanied by the accumulation around these islands of beds of shingle and sand (*b 1*), which as the islands became submerged were spread over them also, and in the form of gravel and sand (*b'*) extended over England as the submergence progressed, up to that level to which the progress of this great depression brought the sea-line—the depression increasing greatly from Eastern Norfolk both southwards and westwards, but mostly in the westerly direction. In consequence of this the ice that, at the commencement of the glaciation, had flowed from the Pennine to the only sea of the presence of which we find any evidence in England at that time—that of the Upper Crag, and its first extension by this movement in East Anglia, changed gradually the direction of its flow, so that, after receding with the progress of the submergence, it took a different direction in accordance with the altered inclination of the country, and with the deepening of the sea southwards and westwards. Thus as emergence brought the shallowest area (which was now the eastern) first into the condition of land, and the more elevated parts of this area became islands, the ice extended over these in its way to the sea, overwhelming them with its moraine of chalky clay (*d*); and as it thickened in the channels between these islands, it cut out and destroyed the gravel which had formed there, and then, as the general mass of ice increased, crushed out and pushed forward most of the moraine first accumulated, so as to overwhelm other islands with it as it reached them. I also showed the way in which, as it followed the retiring sea, this moraine was pushed into it as a mudbank, which covered the gravel and preserved it until the ice thickened sufficiently to cut out more or less the moraine-covered gravel and replace it with fresh moraine. I also explained how this ice,

though passing over these islands, issued mainly to the sea by glaciers through the channels between them, which have since become our river-valleys, though, from the greatly different inclination of the country, this in the case of the Trent and all the rivers flowing to the Wash, took place in the reverse direction to the present flow of those rivers; and how, in consequence, the moraine of Chalky Clay laid down in these channels had, upon the recession from it of the ice, been overflowed by the sea up to the level which then, *according to the different inclination of the country*, corresponded with the sea-surface; so that gravel, which was merely a continuation of that upon which this moraine had as a mud-bank been first pushed, became spread over the moraine within this limit of level. In the north-west of England, where, from the depression being greatest, the water was deepest, the moraine was, I endeavoured to show, extruded not in this way, but beneath the sea, thereby giving rise to the Lower Boulder Clay of that region (D')—a process in which I regarded the Purple Clay of Yorkshire (D) also as having begun, though ending by terrestrial accumulation after Yorkshire had emerged, the material of that clay having been moraine furnished by ice flowing from the Tees valley southwards along the east side of Yorkshire, which was recruited by ice from the Westmoreland mountains crossing the Pennine, and bringing the Shap blocks.

In tracing the first part of this great movement of subsidence and elevation, I explained how, in proportion to its contiguity to the ice, the sea-bed became the receptacle of chalk-débris and chalky silt, produced by the action of the land-ice upon the Lincolnshire and Yorkshire Wolds; and that this, before the extension of the depression had carried the sea over all England, and while some of the Mollusca of the Crag which appear to have since become extinct yet survived, gave rise to the Cromer Till (*b 2*), a local modification of the sands *b 1*; while the actual submoraine of the ice of this date, and from which the silt, mud, and chalk-débris of the Cromer Till proceeded, is represented by the Basement Clay of Holderness (B), which is chiefly composed of a reconstruction of the Jurassic clays and hard chalk of Yorkshire, and in the upper part of which, as the ice was receding from it, thin beds of sand containing the remains of these extinct Mollusca were formed by the intruding sea. I then described how, as this recession went on, the Cromer Till changed to a brick-earth mud (*b 3*), which, in proportion to its propinquity to the Wold, was interstratified with, or even made up of chalk-silt and fine chalk-débris, and which, towards its close (and before the change of movement to one of elevation gave rise to an advance of the ice, and to the overspread of this mud by the gravel *c*) was contorted by the grounding in it of ice detached from that which rested on the Wold, and bringing thence masses of the moraine of reconstructed chalk extruded there, which were thus buried and left in the mud and subjacent Till; so that in this way the sand and gravel *b'* represented this brickearth in the parts more distant from the ice—*b 1* and *b 2* having been deposited before the progress of the depression had carried the sea from East Anglia, generally over Eng-

land, but the whole of them (*b 1*, *b 2*, *b 3*, and *b'*) representing the formation of the sea during this great subsidence.

Further, I described how the ice of the Chalky Clay at its greatest extension in East Anglia (and probably as the first step in the general recession of the ice of the great glaciation), by receding from the plateaux and uncovering the moraine there for vegetation to spring up on it, but still occupying the valleys, had intercepted the drainage from the plateaux, and so given rise to the lagoon deposit of Hoxne, with its palæolithic implements, mammalian and arboreal remains; and how this deposit had been denuded by the effluent water proceeding from the edge of the ice which rested on the high land of Western Norfolk, and had also become draped with the finer material which arose from the washing-out of moraine in North-west Norfolk by the torrents of this water that rolled the stones in it into the cannon-shot form. Then, after describing how, in such valleys of East Norfolk and Suffolk as had at the time of this recession emerged, much of the gravel in them was formed while the ice was vacating them, I examined and traced the successive emergence of the water-partings between the drainage flowing to the Wash and that flowing to the Severn (over one of which, that between the Welland and Avon, the Lincolnshire red-chalk débris had been carried into the basin of the Severn system), as well as of the partings between the drainage flowing to the Severn and that flowing to the Thames.

In all this the main feature for my guidance was that great increment of depression westwards and southwards, the recovery from which has so complicated the problem which I am endeavouring to work out, but which gave rise to phenomena in no way analogous to a renewal of those which accompanied the progress of the depression, because during that recovery, and before even the larger part of this had been accomplished, the major glaciation had begun to diminish in its intensity. These phenomena I now proceed to trace.

The rivers, other than those of Lincolnshire, Norfolk, and North Suffolk, which flow to the Wash are the Welland, Nen, Great Ouse, and Cam; and their valleys, though modified by the land-ice as far as this extended, having been in existence before submergence began, the partings which now divide the drainage flowing through them to the Wash from that flowing southwards to the Thames, or westwards to the Severn, became by this increment of depression lowered relatively to their Wash extremity, while they were elevated relatively to the southern and western extremities of the valleys of the Thames and Severn systems. Thus the sea which, from the westerly and southerly increment of depression, still covered all but the highest elevations of the Thames and Severn systems, had access to these four Wash valleys from the west; while what is now the seaward extremity of these four valleys was blocked by the ice, which, though in retreat, still continued in mass over Lincolnshire, and thence northwards to the Pennine. While this was so with the Welland, Nen, Great-Ouse, and Cam valleys, the Little-Ouse and Lark rivers had, by the emergence of Norfolk and North Suffolk, come into existence, and

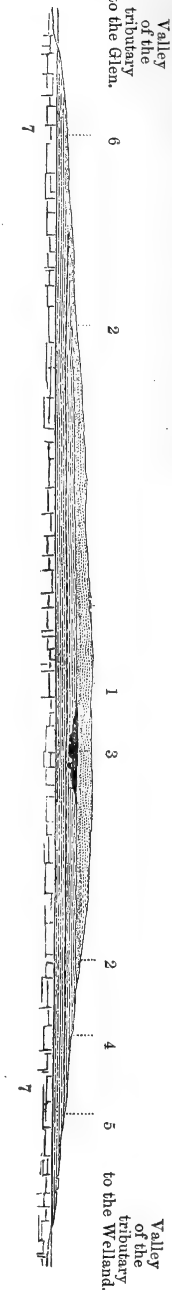
poured their waters into the wide expanse of flat country around the Fen into which these other four valleys opened. On the parts vacated by the ice in its retreat which were above the sea-level, swamps and marsh-accumulations formed, in which were preserved the shells of freshwater Mollusca; and one of these, within the Welland system, was disclosed in the making of the cutting at Casewick on the Great Northern Railway (in the north centre of sheet 64), and is described by Prof. Morris in the ninth volume of the Journal. It lies at an elevation of about 110 feet above O. D., and crowns the parting which separates the valley of a rivulet tributary of the Welland, from that of a tributary of the Glen (a small river which falls into the Welland near the Wash), and is overlain and overlapped by a sheet of gravel which has been cut off by denudation in the direction of either valley. By permission of Prof. Morris, and of the Council, I here give that section (Cut i.).

When the ice of the Chalky Clay was at its greatest extension, and the Fen country deeply buried under it (see map of the Chalky Clay accompanying first part of this memoir, Q. J. G. S. vol. xxxvi. pl. xxi. Map 1), the site of Casewick cutting was of course buried under that ice, and the Oolitic strata on which the freshwater bed rests were undergoing degradation by it; but as the ice retreated this site was left as a low eminence of bare rock, the drainage flowing through the lower levels beneath it. Upon this low eminence, just out of the water, the freshwater deposit, No. 3. of the woodcut, was formed.

Although the ice was now re-

Cut i.—*Section in Casewick Cutting. Length 39 chains.* (From Journal, Vol. ix. p. 319.)

[On the Great Northern Railway, 5 miles from the Northern and 15 miles from the Eastern edge of Sheet 64.]



1. Gravel and sand in wavy seams.
2. Sand and fine gravel, with fragments of Belemnites.
3. The Freshwater deposit with 10 species of living land and freshwater shells.
4, 5, 6, & 7. Members of the Oolitic series.

treating in consequence of the diminution in the great Glaciation, the outflow of water from it was not due to that; for this outflow is the concomitant of land-ice whether in advance or retreat; and it is estimated by Rink that five sixths of the snow which falls on Greenland passes away as water through the land-ice to the sea, the melting of the surface of this ice in summer causing rivers to run over it, which pour in torrents and cataracts through the fissures in it*. At an earlier stage in this retreat—*i. e.* after the ice had uncovered the plateaux of Eastern Norfolk but still occupied the valleys there, through which it still reached the North Sea beyond the present limit of that county—I have described this water, where it came from the ice still lying high on Western Norfolk, as flooding much of this uncovered part, and giving rise to the cannon-shot gravel and the sand associated with it; but in general the escape of this water is beneath the lowest part of the ice. In Greenland it issues from beneath this, where the ice escapes as glaciers through the seaward extremities of the channels it fills, which are called fiords from the point where the ice stops in them. In England these channels were the valleys which, having been in existence before the submergence began, became channels as they went down, and again became so during emergence. Since the westward and southward extremities of the four Wash valleys already named, where the sources of the rivers that now occupy them lie, were more depressed than their eastern, proportionally to the westerly and southerly increment of depression, and these eastern extremities were blocked by the retreating land-ice and by the emergence of Norfolk, the effluent water from that ice which issued southwards and westwards along these channels, and was augmented by the drainage from the emerged land, had no escape after the partings between them and the Thames and Severn systems had emerged; so that it rose and overflowed many of the low partings which separate the valleys of the tributaries of these Wash rivers from each other, one of which low partings is that of Casewick; and thus the swamp deposit, No. 3 of Prof. Morris's figure, which, after the ice had uncovered this tributary parting, but while the water in the valleys had not risen to this level, had been formed upon it, was overflowed and covered with gravel by that water. This gravel was washed away from the slopes, and left on the low partings, and in successive terraces below these partings, as the water-level fell, in the way in which it has been supposed to do by those who have attributed such gravel to the action of rivers running at these high levels, and before the valleys were excavated.

Gravel which, in my view, is of similar age and origin is distributed over the drainage-area of the Cam (in central part of Sheet 51), and crowns tributary river-partings belonging to the Cam system in a similar way. From its association in places with small beds containing freshwater shells, it has been referred by Mr. Jukes-Browne to an ancient river-system, the course of which he considers to have been in the main almost at right angles to the present river Cam;

* Kelland, in vol. xxxiii. of the Journal, p. 143.

but with this he has associated the *Cyrena*-gravel of Barnwell, March, and other Fen localities, which I shall in the sequel describe as altogether distinct and posterior*. As an example, he describes this gravel of an ancient river-system as crowning a narrow ridge, several miles in length, which stretches nearly at right angles to the Cam, and is broken through by that river. On the south of the Cam this ridge forms the drainage-parting of two streams which run parallel and very near to each other; and his hypothesis is that the *crest* of this ridge represents the bottom of the ancient river, which separated into two streams, each of which has cut down a valley for itself on either side of the original river.

Space does not allow me to point out all the objections which offer themselves to this view; nor is it necessary to do so, because it seems to me that, by referring this gravel to the water just described, its position, crowning as it does the parting of two tributaries of one of these Wash rivers within the area of that lacustrine expanse, is entirely consistent with the conditions which I trace as having accompanied the retreat of the ice and emergence of England. It should be stated, however, that this gravel passes eastwards into that which I have, in the first part of this memoir, described as due to the effluent water of the land-ice at an earlier stage of its retreat, and before it had ceased to reach Norfolk,—and that southwards Mr. Penning (a colleague of Mr. Jukes-Browne in the Geological Survey of Cambridgeshire) has, in the Society's Journal (vol. xxxii. p. 203), described the same gravel as continued by patches "almost to the top of the chalk escarpment." These patches, among which are some of those referred by Mr. Jukes-Browne to his ancient river-system, Mr. Penning describes as in some places resting on, or else taking the place of, the Chalky Clay; and he gives a succession of elevations occupied by them from 110 up to 370 feet. He also refers them to successive terraces of this supposititious river, which must have had its rise at a greater elevation than 370 feet, though within fourteen miles of low-lying Cambridge, and though the parting between the drainage to the Cam and that to the Thames (by the Stort) hardly reaches 300 feet†. Looking at the physical features of the country drained by the Cam and its confluents, and the position also of the Chalky Clay, and of the bed of brickearth near Mildenhall and Brandon intercalated in it, such a river appears to me an impossibility; for in a question of this sort one group of phenomena alone must not be kept in view and the rest ignored, but an explanation must be sought which will bear the test of reconciliation with all the other phenomena bearing upon the question involved. Now the bed of brickearth at Mildenhall, which is overlain by the Chalky Clay as well as underlain by

* Post-tertiary Geology of Cambridgeshire, p. 65 *et seq.*

† The contour-lines of elevation in the Map annexed to Mr. Penning's paper show this parting as between 300 and 400 feet; but I have ascertained from the Ordnance Survey Office that the whole of this parting (which extends from the 36½ mile post from London, on the Great Eastern Railway, nearly to the 39th) is really under 300 feet, the highest bench-mark (which is 302 feet) being on a bridge over the railway.

it (and in which Mr. Skertchly has found palæolithic implements), is between 200 and 300 feet lower in elevation than the highest patch of gravel attributed by Mr. Penning to this river, coming into existence after the Chalky Clay, though that patch is hardly twenty miles S.S.W. of it; and I fail to see how this river-denudation, altering altogether the drainage within the Cam system, and converting river-bottoms into hills which separate the old stream into distinct rivers, could have taken place after the Lark valley (to the drainage of which the Mildenhall brickearth was due, as that of Brandon is to the drainage of the Little-Ouse valley) had acquired its present form, and this brickearth been overwhelmed with the Chalky Clay—as I also cannot believe the postulate of Mr. Jukes-Browne, that a river can convert the centre of its bed into a hill. Moreover, how can such an enormous excavation by river-agency have thus taken place in the Cam system, when the valley of the Stort, which is divided from it by this parting of less than 300 feet elevation, has, like the valley of the Lea, and all the valleys of Essex, Suffolk, and Norfolk, undergone no material denudation since the ice of the Chalky Clay deserted them, as is shown by the plunge of the Chalky Clay into them, which I described in the first part of this memoir?

On the other hand, the whole of the phenomena appear to me to be consistent and mutually supporting in the way in which I have traced the case through this memoir*; for, at the time when this brickearth accumulated, Norfolk and Suffolk had, owing to the decrease of original depression in that direction, emerged, and the ice had retreated from those counties and the counties to the south of them, but still continued over parts of Sheets 69 and 70, and thence northwards. The drainage from West Suffolk, while thus emerging, flowed into the low country of Sheet 51, whence, by the increment of depression westwards, it escaped in that direction, if any of the partings separating the Wash rivers from those of the Thames or Severn systems continued then submerged—and if not, by that part of Sheet 69 to which the ice did not reach; and from this drainage the Mildenhall brickearth originated. A temporary advance of the ice in this receded position (as stated at p. 499 of the first part of this memoir) then took place†, which covered this

* Except that in the first part of this memoir I referred the transit of the Lincolnshire red and hard white chalk into the gravel of the Trent system to the time when the excavation of the Steeping valley was effected by the effluent water of the ice of the Chalky Clay, after its retreat to the Lincolnshire Wold. As, however, the transit of this chalk must have been either when the waterparting between the Avon and Welland was submerged, or else when it was overridden by the ice, I see now that it preceded the excavation of the Steeping valley, and that this chalk must have been dropped by floes that took it up from banks of the moraine which was carried by the ice into the Avon valley at the time of its greatest extension in that direction (as represented by the delineation of the Chalky Clay in Map 1), when it issued into the sea over the Severn system by way of the valleys of the Welland and Avon.

† Such an advance is conceivable to me without resort to any oscillation of climate, by supposing that the recovery from the Western depression gained upon the gradual diminution of the ice, which was taking place by the wane

brickearth with chalky clay; and it was while thus advanced, but when the partings of the Wash valleys from the valleys of the Thames and Severn systems had fully emerged, that the effluent water from it, as well as drainage from the emerged land beyond its limit, which it dammed up, gave rise to the lake-like water thus described. It seems to me, therefore, that the freshwater bed in Casewick cutting and the brickearth intercalated in the Chalky Clay in West Suffolk are nearly coeval, both having arisen on places which, when the ice of the Chakly Clay was at its greatest extension, were deeply buried under it, but which were vacated by its retreat to Sheet 69—the one of them having been overwhelmed by the ice during its temporary readvance, and the other by the water-rise which was the consequence of that readvance.

To render my views intelligible, I give the little Map (No. 6, Pl. XXVI.) to represent what I conceive to be the conditions of the country at this time. It comprises the same Ordnance sheets as the Map No. 2 given in the plate to the first part of this memoir; but the scale being only half of that (linear), the rivers which are delineated in No. 2 are omitted from it, except the Trent, the Avons of Warwickshire and Somersetshire, and the Thames. The Map No. 2, accompanying the first part of this memoir, represents the condition to which the area comprised in it had been brought by from 200 to 250 feet of emergence from the maximum depression described in Stage II., and before the ice of the Chalky Clay reached its greatest extension (that extension being represented by the limit shown by the line in Map 4 in the present, and by the distribution of that clay delineated in Map 1 of the previous part of the memoir); and in it the water-partings between the Wash rivers and those of the Thames and Severn systems are shown as still submerged, for they were parts of the channels or fiords by which this ice issued to the western sea. The Map 6, on the contrary, shows these water-partings all emerged, and the land area as extended in proportion to the increased emergence, regard being had to the original increment of southerly and great westerly depression. The ice having retreated not merely from the plateaux of East Norfolk and East Suffolk, but also from the valleys of that region, which had now all emerged to something above their present level, as well as from the various other issues described in the first part of this memoir except that of the Trent, is represented as still extending over the low ground of the Fen country into the north of Sheet 51, its extremity overwhelming the brickearth of the Lark and Little-Ouse valleys, and causing the water in the valleys of the Welland, Nen, Great Ouse, and Cam, thus blocked up by it, to rise and overflow the low water-partings which divide tributaries of these respective systems, such as that of Case-

of the glaciation; so that the issue of the ice to the sea by the Trent valley (which of all the issues by which it passed to the sea was the one that the ice last retreated from) was checked, and the area of the inland ice in consequence proportionally extended, thus causing the part of it covering the Wash to advance over Sheet 65 into 51, as shown in Map 6, Pl. XXVI.

wick and the ridges described by Mr. Jukes-Browne. This water is represented in Map 6 by the unshaded spaces in Sheets 45, 46, 47, 51, 52, 64, 65, and 70, and the sea-water by lines. The ice is shown as still issuing by the (reversed) valley of the Trent to the western sea, but as having retreated from all the other issues; the parting between the Trent and Weaver systems being between 800 and 900 feet below the elevation of the gravel of the great submergence with molluscan remains at Minera Mountain, which is little more than 30 miles west of that parting, and 800 feet below that with these remains near Macclesfield, at a less distance north of it, this part of England was still submerged.

The sheet of gravel in the valley of the Ivel, a tributary of the Great Ouse, which rises to about 140 feet above O. D., near Biggleswade, and which, in the first part of this memoir (p. 482), I doubted being the gravel *c*, is probably part of the gravel thus arising from the blocking-up of the Great-Ouse valley; and that part of the gravel not overlain by the Chalky Clay in the valleys of the Welland and Nen and their tributaries, which is much above the level of the rivers, has also, I think, originated from this cause; for as the depression traced in Stage VI. only raised the marine extremity of the Wash rivers some 30 feet above its present elevation, it could not have raised the water-level of these rivers to any greater extent; and though the increased precipitation, which I propose to show accompanied that depression, probably raised this level further, it does not appear to me that it could have done so to the extent indicated in the foregoing description, nor would the position of the *Cyrena*-formation at Barnwell be consistent with it.

Although during the emergence a gradual recovery from the southerly and westerly increments of depression was going on, yet, unless there was no upward movement at all in the eastern direction after Norfolk and North Suffolk had emerged, this emergence must have extended England in the direction of the North Sea beyond its present limit. This we shall see it did, and also that the subsequent phenomena show that the present relative inclination of the east and west sides of England was not fully attained until after the second (or minor) glaciation; but when, by the complete disappearance of the ice of the first (or major) glaciation from their neighbourhood, the four Wash valleys, already referred to, ceased to be blocked up by it, as well as received no water from this source, they became occupied only by the surface-drainage of their respective catchment areas; and their rivers thus resulting (save to the extent to which their flatter fall and the greater distance of their mouths at this time may have raised their surface by retarding their flow) ran at the same level as they now do; for as they have no excavating power now, but, on the contrary, have filled their valleys with one unvarying sheet of alluvial mud, *à fortiori* they could have had none when their fall was less.

The same remark applies to the Thames and all other English rivers draining eastwards, save that their valleys never were blocked up by the ice, and the level of the fresh water in them thus raised.

The land, as a whole, stood no higher (and in the west and north-west probably lower than now; but the fall of the eastern rivers was longer and flatter than at the present day, and in that position, by the depression which I shall trace in Stage VI. as having brought in the sea around the Wash, their water-level was raised; so that, in some places near their entry to the sea, the freshwater deposits of some of these rivers which flow eastwards pass up into beds containing marine shells intermingled with fluviatile, while nevertheless, as at Clacton, these freshwater deposits are actually overflowed by the present North Sea. Before describing these, however, it is necessary to trace more precisely the progress of the emergence of the valley of the Thames, and of the parts connected with it.

In the first portion of this memoir I said that the gravel *f* of my figures, though called "*gravel of the Thames valley*," is of Glacial age, and demanded a special examination. It has been regarded by geologists as a deposit of the Thames river when this had not excavated the valley in which it runs below the level at which such gravel occurs*; but in my view this gravel, except to the extent that it has become mixed up with the *Cyrena*-formation, has no more connexion with the Thames than it has with the Severn, its relation to both those rivers being the same; for it accumulated beneath the sea when the valleys of both, and probably the lowest of the partings between them also, were submerged (see Map 6). In distinguishing it by the letter *f*, I do not mean to imply that it is all of later origin than that marked *c* or *e*, or even than that of maximum submergence (*b'*), but only that it emerged later. Its bottom layers might indeed, unless there was a destruction and re-accumulation of the gravel-material by tidal movement during the emergence, represent gravel even older than that of maximum submergence, since the lower grounds must have become submerged and received a deposit of sand and gravel before the higher; but as in that part of it which occupies East Essex there occur abundantly fragments of stone from the Weald which I have not only never detected in the gravels *b'*, *c*, or *e*, but which, according to the progress of the emergence of the south of England traced in the sequel, could not have been brought by rivers from the Weald until after the stage in that progress when the retreat of the ice of the Chalky Clay began, it is probable that such destruction and re-accumulation did go on, especially since we get no such thick accumulation of this gravel as is found in the case of the gravel of the Severn area, which at Mickleton (where it represents *b'* and *c*) is 80 feet thick, whereas this of the Thames valley rarely exceeds, and seldom reaches, a thickness of 20 feet. These fragments, which seem to be of the Kentish Ragstone, are deeply pitted externally, and, though small and much worn, are thus identifiable with larger and more angular fragments similarly pitted which are strewed over the Lower Greensand heights around Maidstone, up to elevations exceeding 300 feet, and form the chief constituent of the gravels of the valley of the

* Spurrell, Quart. Journ. Geol. Soc. vol. xxxvi. p. 546.

(Kentish) Stour at elevations up to 250 feet within the chalk escarpment.

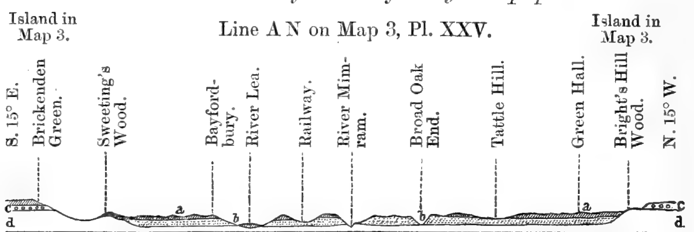
East of the line of fig. VI. which accompanies the first part of this memoir, in which figure it is shown at elevations between 80 and 100 feet), this gravel *f* occupies lower and lower elevations, terminating eastwards, on the north side of the Thames, in the low escarpments of West Tilbury in fig. XXXII. and Fobbing in fig. XXX. These escarpments face the Thames or its creeks; but from its eastern extremity at Fobbing this gravel crowns an escarpment which rises towards Romford (near which town it is crossed by the line of fig. XXXIII.), and *faces the side of the valley*, as shown by figs. VI. and XXIX., which cross it in this part. Where it thus faces inland, this escarpment attains an elevation of 117 feet; and as the elevation rises, the space between the escarpment and the valley-side, against which the gravel originally rested, diminishes from the six miles shown in fig. VI. until, just west of the line of fig. XXXIII., it lies undisturbed against the valley-side, which it continues to do from thence westwards to the Lea river, up the valley of which it extends continuously, until, inosculating with *c* and *e* (in the south-west of Sheet 47 and south-east of 46), it passes both under and over the Chalky Clay. As it thus stretches up the Lea valley, however, from Tottenham to the part where it passes under the Chalky Clay in the south-west of Sheet 47, it occupies *the western slope only* of the valley, as shown in fig. XXXIX.

On the south side of the Thames this gravel rises at Wimbledon Common and Richmond Park to elevations of 170 and 181 feet; and there also it terminates in the direction of the valley-side in an escarpment, as shown in fig. XXVIII., several miles intervening between this escarpment and the valley-side up to which it must once have lain. West of the line of fig. XXVIII. it, for the most part, lies up to the valley-side, both north and south of the Thames, as shown in fig. XXXVIII., though over most of the south part it has been so much removed as to show itself only in patches, as represented in Sheet 7 of Map 3. This map is a careful reduction from all Sheets 7, 1, 2, and the southern portions of 46, 47, and 48 of the Ordnance one-inch-to-the-mile map; and upon it are delineated the gravels *c* and *e*, *f*, and *g*; but it must be borne in mind that, owing to the water of the *Cyrena*-formation, described in the sequel, having risen to the level up to which most of the gravel *f* remains, the sand which constitutes bed ϕ 3 of that formation may be more or less undistinguishable from it, and thus may in places form a portion of what, both in the map and in some of the lines of section which I have given across it, is represented as gravel *f*; for it is only where brickfields occur, either in beds ϕ 2 or ϕ 4 of it, that the *Cyrena*-formation can be shown. The scale of Map 3 does not admit of the delineation of the small patches of the gravel *b'* which have escaped destruction, nor, without obscuring the other features necessary for my explanations, of the delineation of the Chalky Clay; but the distribution over it of that clay may be seen by comparing it with the corresponding part of Map No. 2,

given in the first part of this memoir, of which, as regards the emergence represented there by the shaded (and in the present map by the black) areas, Map 3 is an enlargement, showing the emerged parts in the greater detail which the scale of it allows*. The valleys, which have now become occupied by rivers, were, during the advance of the ice of the Chalky Clay, channels between the islands (and also inlets from such channels) which came into existence from the emergence of the islands; and by these channels, in the parts to which the ice reached, this ice, notwithstanding that it overwhelmed such islands as came in its track, issued to the sea; and thus it is that the gravel *f*, inosculating with *c* and *e* up both the channel of the Lea, in Sheet 1, and the channel of the Colne in Sheet 7, is all one with that gravel—passing in both channels as *c* under, and as *e* over, the Chalky Clay, as described in the case of the Colne in the first part of this memoir (p. 508).

Making use of the Survey maps so far as available, rather than my own, as free from the objection of having been constructed in accordance with my views, I, for a similar reason, avail myself of the section given by Prof. Hughes in his paper on the two plains of gravel in Herts in the twenty-fourth volume of the Journal (p. 284), in further illustration of this part of the case.

Cut ii.—*Section from Prof. Hughes's paper.*



a. "Boulder-clay" (the Chalky Clay, *d*, of my figures).
b. "Subangular gravel, sand, and loam of Lower Plain, with boulder-[chalky] clay under it, in it, and on it" (*c* and *e* of my figures).
c. "Pebble-gravel of Higher Plain; large percentage of quartz" (older part of *c* of my figures).
d. "Chalk and Tertiaries."

N.B. In Prof. Hughes's paper the points of the compass at the ends of the section are by inadvertence reversed.

The line of this section is shown on Map 3 by that marked A N, and is in the part where *c*, *e*, and *f* thus inosculate as "gravel of the lower plain;" and Prof. Hughes, in his description, observes that the gravel of his lower plain (*b* of his section, and the newer part of *c* of this memoir), which is that of the channel (the gravel of the higher plain being that on the islands, viz. the earliest part of *c* of this memoir, which had emerged before the ice reached it), has the Chalky

* See the reference to and explanation of maps and sections at the end of the memoir.

Clay "under it, in it, and on it." The gravel thus having "*the clay under it*" corresponds to that which is shown under the letter *e* in fig. VII., and owes such position to the ice in the channel having wholly cut out *c* of this memoir, and laid down the morainic clay *d* in its place. This, from its having been below the sea-level, on the retreat of the ice in the channel was overflowed by the sea, and so received a deposit of gravel (*e*) upon it. The gravel with "*the clay in it*" is that where this cutting-out of *c* has been only partial, so that, while the morainic clay received *e* in the same way upon it, it nevertheless rested upon a part of *c*; while the gravel "*with the clay on it*" is the normal condition, i. e. *c*. In the part of the Lea channel which is crossed by fig. XXXIX. the ice has laid its moraine of Chalky Clay (*d*) on the islands on either side of the channel, but not in the channel itself; so that the gravel *f*, which was deposited by the sea after the retreat of the ice, lies at a lower level than any part of the moraine here. Where this morainic clay rests on the gravel *c* about Finchley (nine miles south-west of fig. XXXIX), it is at an elevation of about 300 feet, and must, as in the case of the islands at either end of Prof. Hughes's section, have been so laid terrestrially*; for as this is at least 100 feet above the elevation at which the general evidence indicates the sea having stood in the west of Sheet 1, and east of Sheet 2, when the ice retreated from there, it must have emerged before the ice reached it, being at the extreme southern limit to which the Chalky Clay extends. In other places where, in thus previously emerging (as e. g. in fig. XXXIX., and one part of Prof. Hughes's section), the earlier part of *c* was previously washed off, the morainic clay has been laid down terrestrially on the Eocene or Chalk. The gravel of the higher plain is. as Prof. Hughes says, marked by the greater abundance of quartz and quartzite pebbles. This shows its affinity to the gravel of greatest submergence, which, in the westward direction especially, is conspicuous for the abundance in it of those pebbles; while the gravel of the lower plain is conspicuous by the abundance in it of the débris of the moraine carried into the channels by the approaching ice, the gravel on the islands (*i. e.* that of the higher plain) having emerged before the ice approached near enough thus to change the character of its constituent material.

In the first part of this memoir I observed that, since the water-parting between the drainage systems of the Thames and Severn by way of the Swill brook (a tributary of the Isis in Sheet 34) and the Avon of Wilts and Somerset is about 150 feet lower than that by way of the Evenlode and Stour in Sheet 44 (over which the red chalk carried out into the Severn system had come round into the upper part of the Evenlode valley), it must, even after allowing for some diminution in the degree of submergence in that direction, have emerged later; and until this took place the systems of the Thames and Severn must have been connected by sea, but gradually narrowing from the broad open strait shown in Map 2 (in first part of memoir) until the valley of the Swill brook became part of a narrow strait con-

* See note to explanation of maps and figures at end of memoir.

necting the Thames valley with the greatly expanded Bristol Channel, as shown in Map 6 (Pl. XXVI.). Over this parting (which is Oxford Clay) a considerable accumulation of gravel is spread, chiefly composed of flint*, though it is distant ten miles from the nearest chalk, and none of the brooks around it flow from the chalk direction. Upon the emergence of this parting, the valleys of all the Thames system became estuarine, from which, as emergence proceeded, they became fluviatile; the valley of the Avon of Wilts and Somerset thus divided from the Thames system, and that of the Avon of Warwick, Worcester, and Gloucestershires, which is divided from this system by the partings whose emergence I traced in the first part of this memoir, passing through a similar phase. Owing, however, to the increments of depression already traced, the fall of the Thames system was flatter, while that of the two Avons was probably steeper than now, so that when we take up the history of the Thames in Stage VI. we shall find that the mixture of its fresh water with the salt had come to take place considerably to the east or north-east of the part where this now occurs, and so that the rivers of Essex entered the estuary of the Thames considerably to the eastward of the present coast of that county when the time at which that stage begins had arrived; for the freshwater-beds of that stage on the Essex coast descend below the present sea-level.

In the case of the main valley of the Severn the case is more complex; for since at its Bristol-Channel extremity the evidences of submergence cannot be satisfactorily traced beyond 750 feet, they must have been 500 feet at least more than this at the source of this river, because the head of one of its upper tributaries (the Perry, in the S.E. of Sheet 74) is only 12 miles south of Minera Mountain, on which Mr. Mackintosh has found the gravel (*b'*) with marine shells at 1230, and without shells at 1350 feet†. This and two other tributaries of the Upper Severn, in Sheet 73, are separated from the drainage flowing by the Weaver and Dee to the Irish Sea by low water-partings of about 300 feet elevation. It is evident therefore that unless a more complete recovery from this increment of depression in the direction of North Wales and Lancashire had taken place, when the partings between the Thames and Severn systems emerged, than the general purview of the case appears to me to indicate, the valley of the Severn must have been in connection with that of the Dee and Weaver, and Wales have been completely separated from England by the strait thus constituted, for some time

* See the note engraved on the Geological-Survey sheet No. 34, 7 miles S.S.W. of Cirencester. The flint-gravel 3½ miles east of this, described by Lucy, *loc. cit.* p. 35, and which he says contains mammalian remains, probably represents the time just after the parting had emerged, and the Swill and Minety brooks had become small rivers opening into the estuary of the Thames and Isis; for that gravel is not on the parting, but in the flat valley where these brooks enter the Isis, and the flint of which it is composed was probably derived from the gravel *on* the parting.

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 361. Mr. Mackintosh states that gravel as much rounded as that in which shells occurred extends up to 1550 feet (p. 368); but I do not at present see sufficient reason for thinking that the submergence reached that height.

after the Thames-system partings had emerged, and that system must have become entirely a river-system, if, indeed, this condition of a strait did not even endure until the depression of Stage VI. Mr. Maw describes the gravel of the Severn valley with marine Mollusca as extending down to the modern river alluvium as far up that valley as Ironbridge and Shrewsbury*; and it seems to me that this may be the result of the state of things just mentioned, for the Bristol-Channel extremity of this valley must, from this great difference in the depression, have become land nearly as soon as its source extremity, which is now some hundreds of feet higher above the sea than the Bristol extremity. In the case of the principal tributary of the Severn, the Warwickshire Avon, this was different, because the course of that river being from north-east to south-west, the depression of the different parts of its valley was pretty uniform; so that in emergence it passed from the marine to the estuarine (see Map 6), and from that to the fluviatile condition in the due gradation of its various portions; and thus, contrary to the case of the Severn, the gravels of the Avon at the lower elevations contain freshwater shells and mammalian remains †.

The phenomena presented by the gravels of the Trent system must be complicated by causes partly similar to, and partly dissimilar from, those affecting the gravels of the Severn,—similar in that the valleys of the westernmost part of the Trent system, from their contiguity to the area of greatest depression, emerged later than the lower or north-eastern part of that system; but dissimilar in that the valleys of the lower part of that system continued to be occupied by the land-ice after those of the upper part had ceased to be so. The phenomena of the Trent system subsequent to the Chalky Clay therefore require an examination by themselves, which I have not the materials to make, but which, when attempted, should be made with due regard to these conditions.

I must here break the thread of my attempt to trace the progress of the emergence of England, by some further remarks on the phenomena connected with the submergence, which are necessary in order to enable me to place before geologists properly those views concerning the whole chain of events embraced by this memoir to which my study of the subject has led me.

In tracing the evidences of submergence during Stage II., I stated that the gravel (*b'*) shown at Cæsar's Camp, in fig. II. of the plate to the first part of this memoir, spreads out over that part of the Chalk plateau of North Hants which skirted the western edge of the Wealden excavation. I have ascertained that this gravel reaches the elevation of nearly 700 feet, the level of the rails in Meadsted Cutting—where (mixed with loam, and containing large waterworn flints) it crowns the parting between drainage falling to the Southampton water and that falling into the Thames (and which is indicated by the letters A P on the continuation of Map 2)—being

* Quart. Journ. Geol. Soc. vol. xx. p. 130.

† Ingram, in vol. xxxv. of the Quart. Journ. Geol. Soc. p. 678, and Lloyd, in vol. xxvi. p. 202.

650 feet; and above this the gravel is in section for a depth of more than 20 feet in places. Thus the highest point to which the New-Forest gravel reaches, and which is shown in figs. V. and XLII. as 419 feet, is much below that of maximum submergence in Hampshire, so that the gravel at Bramshaw telegraph, shown as *b'* in those figures, could only have emerged about the time when the ice of the Chalky Clay reached its greatest extension in East Anglia. Professor Prestwich also describes a bed of gravel mixed with sandy clay on the highest points of the Chalk Down, near Weymouth, which he says ranges up to 730 feet; and this, from his description*, seems to correspond with the Meadsted bed in the time and mode of its origin; so that the evidences of the maximum submergence seem in Hampshire and Dorsetshire to differ but little from those in the Cotteswold region.

In Map 4† (in Plate XXVI.) I have represented what appears to me to have been the condition of England north of the line of the Thames at the culmination of the great depression of Stage II., according to the evidences traced in the first part of this memoir, when, from the whole of England having become submerged and the inclination changed, the ice, which at the beginning of that stage, and when the sea was on the east side of England only, had (by way of the Humber Valley nearly, and from a more northerly direction quite) reached Norfolk, had now retreated to the west of the Chalk Wold, preliminary to its advance as emergence began in the different direction induced by the altered inclination; the limit of which advance is shown by the strong line on Map 4, which marks the limit of the Chalky Clay, the space within this line being covered with a more open tint than is the rest of the area occupied by sea at the culmination of submergence. A comparison of this map with the representation given in Map 1, which accompanies the first part of this memoir, and in which the Chalky Clay itself is shown, will indicate the evidence on which this delineation of the limit of the ice of the Chalky Clay rests; while Map 2, which also accompanies that part of the memoir (and is continued southwards in the plate to the present part), shows the change in land and water between this culmination of the submergence and the time when, towards the close of this advance, about 250 feet of emergence had taken place.

* Quart. Journ. Geol. Soc. vol. xxxi. p. 41. The bed is shown in Prof. Prestwich's plate by black tint, but the distinguishing letter of it is omitted. Its position on the Chalk escarpment in *his* fig. 2 should be collated with that of gravel *b'* in *my* figs. II. to V.

† Constraint of space has obliged me to confine this map to the north of the Thames and Bristol Channel, but the rest of England to the south of it was, with the exception of the higher eminences, all submerged. The chief of these eminences were:—Dartmoor, Exmoor, the highest parts of the Chalk of Wilts, Surrey, Kent, and Sussex, St. Catherine's Down in the Isle of Wight, Leith Hill and Mine Head in the Weald, and the highest ridges of the Hastings beds in Sussex—all of which were islands, and of which Dartmoor may, from its height, have been enveloped in land-ice. The condition to which about 250 feet of emergence brought this part of the submerged country is shown in the continuation of Map 2, in which the shaded parts are, at the western extremity those 400 feet and upwards above O. D., and at the eastern those 200 and upwards, with the intervening area in proportion.

In this map, No. 4, the regions enveloped in land-ice at the time of greatest submergence are left unshaded, while the land not so enveloped, and which consisted of islands, is shown in black, the sea being indicated by a tint of ruled lines. I have not, however, attempted, as I have done in the case of the ice of the Chalky Clay, to delineate the extent to which, as the land rose, the ice in Lancashire and Cumberland and that in Wales advanced. Probably as the water was so deep over West Lancashire, the ice there did not ever extend beyond, and probably never (at least after the submergence culminated) reached, the present coast-line of that county*; but it was along the littoral zone which, at the time to which Map 4 applies, skirted the edge of the Lancashire ice that the gravel with marine shells accumulated, of which the remnant above Macclesfield, at 1200 feet elevation, has escaped the general destruction which took place on the advance of the ice during emergence. On the parts which represent the corresponding zone skirting the Welsh ice, there accumulated similar gravel, of which the remnant long known as present at Moel Tryfaen (just beyond the limit of the map) at 1350 feet, by the Menai Strait, and the remnants lately discovered by Mr. Mackintosh † on Halkin and Minera mountains, at 950 and 1230 feet, formed part, and have escaped destruction in a similar way. I attribute the escape of all these remnants to the ice passing to the sea down the valleys on either side of them as emergence went on, leaving these gravel-capped eminences uncovered in the way that in Greenland hills not covered by ice occur in some places between the great body of the inland ice and the sea, and through the valleys beneath which eminences this ice escapes as glaciers to the sea. When the great glaciation passed away, these valleys were reoccupied by the sea up to the elevation to which emergence had then lowered the sea-line; and gravel of the same kind, but proportionately later, was then deposited in them; but the molluscan fauna not having altered in the interval, the shells in this gravel are much the same as those in the gravel of greatest submergence.

It is not easy to perceive why the great Vale of York, and the part of North Lincolnshire and of Yorkshire between the Humber and the Pennine, has, notwithstanding the presence of the Chalk formation far to the north of this, no Chalky Clay in it; or why the Lincolnshire Wold has an enormous moraine of chalk débris heaped up on its western flank (though not on its eastern), while the Yorkshire Wold is altogether destitute of this feature.

The explanation seems to be that, as the inclination changed from an easterly to a westerly and southerly one, the ice which had, during the formation of the Basement Clay of Holderness (B of figs. XLVI. to XLIX.), issued through the Humber to the sea which had originally been confined to the eastern side of England, was deflected southwards to the sea as this extended over the centre and

* The distribution of the Lower Clay of the north-west of England does not differ materially from that of the Upper Clay shown in Map 5.

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 351.

south of England, so as to pass exclusively along the west of the Wold in Lincolnshire, sweeping all the degraded chalk from the Wold into this Lincolnshire vale, and carrying it down into Sheet 83, where it is heaped into the hills shown by the black tint, in Map 1, representing the Chalky Clay there. Possibly, though I do not think so however, there may be some of this concealed by the alluvium which is extensively spread in the west of the Yorkshire part of the Wold in Sheet 86, or by the gravel which covers so much of the east of Sheet 93, and skirts the Wold escarpment there. Prior to this deflection, the ice thus filling the vale of York and enveloping the wold issued to the sea as a glacier through the Humber, and covered the east of Holderness (which was the preglacial Humber valley) with its moraine, B, while the silt and chalk *débris* from it passed out to sea to supply the material of the Cromer Till (*b 2*). As the ice in thus retiring from the Humber to the west of the Wold uncovered this moraine, the sea took its place, and the Bridlington and Dimlington Mollusca established themselves there; so that their remains (many of which are in the condition in which they were at the death of the animals) became imbedded in seams of sand which occur near the top of B, in fig. XLVI., as well as at Bridlington, and were probably mixed up in this part of the moraine by oscillations in the position of the ice as it was thus changing its direction. This, as shown by the character of these shells (among which are two extinct and highly characteristic Crag forms), when compared with the shells from the gravels at 1200 and 1350 feet elevation, must have been before the culmination of the depression represented by Map 4 had arrived, at which time it was that the masses buried in the Contorted Drift were carried into it, probably from the great accumulation of reconstructed chalk, in Sheet 83, already referred to, and of which the place is marked by an asterisk in that map*; but, to make the case intelligible, I have shown the

* Mr. T. Mellard Reade, in the 38th vol. of the Journal, page 222, seems to be under the impression that these masses consist of chalk; but such is not the case, though the sheets interstratified in the Till below are of unaltered chalk, and, as stated in the first part of this memoir, seem to have been dropped from floe-ice early in Stage II., and are unconnected with the contortions. The masses in question, the introduction of which is due to the agency giving rise to the contortions, were introduced at the close of the Contorted Drift, and are mostly of reconstructed chalk, or the extremely chalky form of the Chalky Clay, and include quartz and quartzite pebbles and other foreign débris, and in some of the inland pits consist of a deposit of chalk silt in paper-like laminæ. Where, as in some cases by the flints being in rows, they look like chalk, the masses consist of glaciated chalk with galls of red clay in them. If, therefore, they were introduced as Mr. Reade thinks, not by the grounding of bergs, but of floe ice, these floes must have frozen to banks of moraine extruded at or about the sea-level, as is the case in many parts of Greenland. The way in which these masses and the contortions cease eastwards along the North-Norfolk cliff as the Contorted Drift in that direction thins, shows, however, that the vehicle of their transport was ice which required some depth of water to float in. I am at a loss to imagine where the Chalk can be, as Mr. Reade supposes, 650 feet above O. D. in Norfolk, so as to have formed cliffs during the accumulation of the Contorted Drift; for I do not think that the elevation to which the beds *b* 3 and *c* rise to form Cromer lighthouse hill (248 feet) is exceeded by any point in Norfolk to the extent of more than a few feet.

sea thus covering the Basement Clay, B, and the ice which enveloped the eastern moorlands as not yet extended down the east of the Wold; though probably it had begun thus to extend, and to take the place of the Basement Clay ice, by the time that the depression culminated. It was the same change of inclination, causing the ice of the Basement-Clay to retire to the west of the Wold, that caused the East-Moorland ice (which had heretofore taken an easterly direction like that of the Wold-ice) to take a southerly direction, and, hugging the eastern slope of the Yorkshire Wold, to take the place over Holderness of the Basement-Clay ice which had thus retired through the Humber; and this ice, bringing with it the Shap blocks, which had crossed the Pennine into the valley of the Tees, originated the Purple Clay (D). Thus this clay, D, is spread over a Basement-Clay moraine corresponding to that of Holderness, which occupies the preglacial valley of Pickering, in precisely the same way as it is over that of Holderness, which occupies the preglacial valley of the Humber; and just as the edge of the one Basement Clay lying against the chalk side of the Old Humber valley, as this rises above the beach-line north of Bridlington, is overspread and overlapped by the Purple Clay, so is the edge of the other Basement Clay lying against the oolitic rockside of the old Pickering valley, as this rises from below the beach-line north of Filey, overspread and overlapped by the Purple Clay also. My personal knowledge of the coast-section northwards ceases at Scarborough; but I am informed by Mr. Barrow, of the Geol. Survey, that the valleys of the coast side of the East Moorlands between Scarborough and the Tees mouth, such as that of the Esk at Whitby and that at Runswick, are similarly filled by a Basement Clay and an Upper Clay; and I infer (especially since, as mentioned in describing Stage VII., nothing corresponding to the Hessle Clay occurs along the coast-section, from the place of fig. L. to Scarborough) that all this Basement Clay is, like that of Holderness and Filey, the moraine of the ice before the change in inclination had caused it to change the direction of its movement, and so give rise to the Purple Clay which overlies it. Having thus originated in a similar deflection of the ice from the same change of inclination that gave rise to the Chalky Clay, the Purple Clay is probably coeval with the whole, instead of only the latter part of this, as suggested in the first part of this memoir, though, from the position and source of the respective ice-streams from which these clays originated, the Purple Clay probably continued to accumulate after the ice had ceased to reach the west of the Wold, and so give rise to the Chalky Clay. If, too, the Shap blocks are present near the base as well as in the upper part of the Purple Clay, the great accumulation of ice in Westmoreland which caused the transit of the Pennine by these blocks must have preceded the rise of the land, instead of being due to it, as suggested in the first part of this memoir.

I think also, on consideration, that the reason why none of the gravel of the great submergence is to be found on the eastern side

of the Pennine is, that throughout the major glaciation the ice filled all the lower ground between the Pennine and the Wold, in consequence both of the less depression of this side during the submergence, and of its having been that originally filled by the ice in its passage to the sea at the outset of the glaciation, when the sea was confined to the eastern side of England; so that throughout the glaciation it kept out the sea until this part had emerged, the ice continuing in this part after it had retired altogether from East Anglia. Thus, instead of the gravels *b'* and *c* having, as suggested in the first part of this memoir, been destroyed over the space between the Pennine and the broken line on Map 1, by the advance of the ice which formed the Chalky Clay, they never existed over so much of that space as is represented in Map 4 as occupied by ice.

The intermittent beds of sand marked *c* in fig. XLVI. seem to have been deposited after the Mollusca, which established themselves on the moraine of Basement Clay (B) as the ice of this retreated, had ceased to live there, no trace of shells having yet been detected in these beds. Their accumulation appears to have accompanied the inroad of the ice of the Purple Clay (D), for they are mixed up with sheet-like fragments of both the Basement and Purple Clays, and are only occasionally present.

There are four particular sources from which erratic blocks have been traced, viz.:—Criffel, near the Scotch shore of the Solway Firth; Eskdale, near Ravenglass on the Cumberland coast; Shap, in Westmoreland; and Arenig, in North Wales. These places are shown on Map 4 with lines indicating the routes which the blocks from them have taken, and the limits to which, as far as known, they have reached. Now Mr. Mackintosh (from whose papers* the lines followed by these blocks, save part of the line followed by the Shap, are taken) states that the blocks and fragments from Criffel, Ravenglass, and Arenig are all distributed over the area occupied by the tint of ruled lines in Sheets 72, 73, 74, 79, 80, 89, and 90 (most of which is of no great elevation); but that none of them, save those from Arenig, occur west of a line corresponding to that which I have represented as the eastern boundary of the Welsh ice. The Arenig blocks, on the contrary, he says are distributed within the part representing the Welsh ice up to elevations exceeding 2000 feet, to which height he in consequence regards the submergence as reaching. Mr. Mackintosh attributes the arrest of the Criffel and Ravenglass blocks at this line to a conflict of currents; but it appears to me to be susceptible of the more simple explanation that I suggested to him, and which he notices in his paper†, but which, as it is part of the case presented by this memoir, I now advert to.

If we regard the Arenig blocks and fragments as having been

* Quart. Journ. Geol. Soc. vol. xxix. p. 351, vol. xxx. p. 721, & vol. xxxvii. p. 361.

† Quart. Journ. Geol. Soc. vol. xxxvii. p. 361, footnote. Mr. Mackintosh objects to this view on the ground that the land-ice from Arenig could not have attained a surface-level of 1500 feet above the present sea by the time it reached the line where I regard it as terminating in the sea. As, how-

carried by the Welsh land-ice from Arenig to the line where this ice terminates, and the gravels with marine Mollusca on Minera mountain occur, their presence over the area shown as Welsh land-ice at much greater elevations than the highest of those places at which molluscan remains have occurred (all of which latter are within the ruled line area) is intelligible; as is also the reason why Criffel and Ravenglass erratics carried from the edge of the English and Scotch ice by floes could get no further westwards; and why these and Arenig erratics carried by floes from the edge of the Welsh ice are alike distributed over the ruled-line area. The track of the Shap blocks eastward I have already, in the first part of this memoir, referred to the land-ice crossing the Pennine; but these passing by land-ice down the Eden to the Solway, and down the Lune to Lancaster Bay, follow thence the distribution over the ruled-line area already defined of the Criffel and Ravenglass erratics (though they have not been yet traced as extending quite so far), and are in that area due to the same distribution by floes as these are.

I now, after this digression, resume tracing the emergence of the South of England, to bring the case in that part to a parallel position to that to which I have, in the first part of this memoir, traced it in the part to which the ice of the Chalky Clay extended; and for this purpose I have given in Plate XXVI. a continuation of the Map No. 2, given in the previous plate, by extending this to the British Channel. It purports to represent the conditions of land and sea when about 250 feet emergence had taken place, and the ice of the Chalky Clay had reached its furthest extension; the parts in shade at the western extremity of this continuation-map being those above 400, and at the eastern those above 200 feet elevation, with the intermediate area in proportion, in accordance with the increment of submergence.

As the evidences of submergence in Hampshire reach (as described, *ante*, p. 682) to more than 650 feet, the inlet in which Mr. Codrington rightly contends most of the South-Hants gravel accumulated could not have become landlocked to the north at the time of Map 2, because the cuttings of the railway from Basingstoke to Oakley and Overton, which traverses the parting between the Thames and Hampshire systems, are all under 400 feet. Some of these have small patches of gravel on them. This part therefore (in the centre of Sheet 12) is shown in the continuation of that Map in Plate XXVI. as a strait connecting the sea over the two systems; and at this time the Thames system was still connected with that of the Severn by the valleys of the Evenlode and Warwickshire Stour, through which came the Red Chalk shown by crosses in Sheet 44 of the first part of Map 2, and for some time longer by

ever, this part of England was at the time near 1400 feet below its present level, and the Greenland ice rises inland to several thousand feet above the sea, and descends in the channels which it has filled so much below the sea-level that Dr. Sutherland says bottom is not found at the face of some of the glaciers in less than 2400 feet (Q. J. G. S. vol. ix. p. 301), I am unable to see the force of this objection.

the valleys of the Swillbrook and Somersetshire Avon in Sheet 34, as shown in Map 6.

With the flint débris of which the South-Hants gravel is chiefly composed is a large admixture of quartz and quartzite pebbles ; and as these abound in the gravel of the plateau around Bournemouth, which was formed in the Hampshire inlet when this had shrunk to small dimensions, and did not emerge until the sea was about 100 feet only above its present level, and all the water-partings between this inlet and the systems of the Thames and Somersetshire Avon had risen far above the sea-level at that time, they could only have been brought into it by some one or other of the group of rivers in Hants and Dorset which emptied themselves into this inlet (and of which the Avon of Wilts and Hants is the principal) from beds of gravel *b'*, of which there are some remnants, mainly composed of these quartz and quartzite pebbles, on the chalk hills of Dorset near the sources of these rivers. River-ice was probably the vehicle of their transport then, as floe-ice was that of their transport into the gravel *b'* ; and this same river-ice drifting out into the inlet carried into the gravel of the Bournemouth plateau the palæolithic implements of the pointed type found in that*, and resembling those from the fluviatile gravel of Milford Hill near Salisbury. This Bournemouth gravel, as Mr. Codrington observes, corresponds, when allowance is made for the one being that of the inlet, and the other that of the rivers Avon (of Wilts) and Bourne, with the gravel of Milford Hill ; the bed at Fisherton near Salisbury, on another tributary of this Avon, corresponding, as he also observes, with the marine gravel G shown in fig. XLII., a formation of the Minor Glaciation, or Reindeer period, described in Stage VII., and with which the mention of Reindeer remains from Fisherton by Prof. Dawkins (Q. J. G. S. vol. xxv. p. 196) coincides.

As the gravel at Bramshaw telegraph (in figs. V. and XLII.), of which the elevation is 419 feet, could not have emerged until near the time when the ice of the Chalky Clay began to retreat from the Norfolk plateaux, its conversion into land must have but little preceded the formation of the Hoxne bed; so that if the implement found by Mr. Prestwich on a talus of the gravel at about 350 feet near Downton, on the slope of the Avon valley within four miles of Bramshaw, had been *in situ*, it would have been that nearest in synchronism to the Hoxne implements which the south of England has yet furnished.

The chalk on which rests the gravel *b'* at more than 650 feet at Meadsted (shown by the letters AP on the continuation of Map 2, and as then emerged) forms the environment of the western extremity of the Weald ; and a section across that extremity, from the chalk environment on the north to that on the south, is given by Sir R. Murchison in vol. vii. of the Journal, p. 353, wherein he shows the extremity of the unshaded space immediately south-east of the letters

* It was in a similar way that the implements found in the gravel *f* of Dartford Heath got into it, which gravel has been on the strength of this attributed to the Thames river. The sweeping by climatic agencies of the land-surface débris into rivers was probably the chief source of palæolithic implements in their gravels.

AP (and which is the apex of the Wealden excavation) occupied by large accumulations of "flint drift" resting upon the Neocomian. Whether this "drift" be gravel, or what it may be, I do not know; but within the same great Wealden excavation, near the centre of Sheet 8, is an important bed of gravel, because it has been described by Mr. Godwin-Austen as having been faulted with the Neocomian formation on which it rests during the earlier part of its accumulation *. The part where this occurs is represented in the continuation of Map 2 as an island in two parts joined by an isthmus; of which two parts, the northern represents the Chalk Down from Gomshall towards Leatherhead, and the southern the lofty Neocomian tract of Leith Hill, Mine Head, and its neighbourhood; the isthmus connecting them being the parting (at about 400 feet elevation) between the drainage flowing to the Mole, and that flowing to the Wey by the Tillingbourne, and over which parting Sir R. Murchison (*loc. cit.* p. 379) describes the same "flint drift" as distributed and resting on the Neocomian sand.

This isthmus was submerged during the time represented by Map 4, and the two parts formed separate islands; but having at the time of Map 2 emerged, the Tillingbourne valley formed the inlet penetrating this island on the west of the isthmus which is shown in that Map; and in this the faulted gravel accumulated, its elevation being 241 feet above O. D., and more than 130 above that of the sheet of gravel occupying the valley of the Wey and its tributaries, part of which is shown under the letter *g* in figs. II. & III. The faulting of this gravel seems to have been connected with the rectilinear disturbances which, with the great denudation to which these gave rise there, have placed the gravel *b'* in the position which it occupies in figs. II., III., IV., and V. Mr. Godwin-Austen describes it, as well as that on Merrow Down †, as including great blocks of greywether sandstone. He also says that mammalian remains have been met with in the lower portion of this gravel.

From this island eastwards the sea is shown as covering the Weald up to elevations which gradually decrease in that direction to 200 feet at the eastern part of the map, but as being in connexion with the sea over the Thames system by way of the (Kentish) Stour, the Medway, the Darent, the Mole, the Wey, and the low ground near Farnham, the elevations of all the partings from the Thames system by any of these being below the elevations on which the representation of the submerged parts of the map is based. Gravels sporadically scattered over some of the parts thus represented as covered by sea occur on the Weald clay, independently of that which at low levels skirts the rivers, and can justly be referred to the action of these when, during Stages VI. and VII. they in flood-time were in greater volume than now. These patches, which are shown on the Geological Survey map of Sheet 6, have been referred by Messrs. Topley and Foster‡ to the

* Quart. Journ. Geol. Soc. vol. vii. p. 278.

† Merrow chalk-down at a much higher elevation is also shown by Mr. Godwin-Austen as capped by gravel, which I presume is *b'* of this memoir.

‡ Quart. Journ. Geol. Soc. vol. xxi. p. 443.

deposit of the river Medway and its tributaries, when the Medway system ran at a proportionately higher level; and in order to reconcile this with even the largest conceivable volume that could be assigned to the rivers, they are compelled to assume an enormous fluviatile excavation as having succeeded (and in a less degree also accompanied) the deposition of this gravel; for the patches reach to upwards of 200 feet above the rivers, and 300 above O. D. The Lower-Tertiary pebbles and subangular chalk-flints which some of these gravel-patches contain more or less abundantly, notwithstanding that they are separated from the Chalk by the Neocomian escarpment, and from the Lower Tertiaries by both that and the Chalk escarpment, and notwithstanding that in some cases the rivers of their neighbourhood do not reach the Chalk, much less the Lower-Tertiary area, are regarded by these gentlemen as having been brought by streams which, prior to this enormous river-excavation, were tributary to those rivers when they ran at proportionately high levels, and being thus tributary, flowed over great areas of Neocomian and Gault, and even Chalk, which have since been removed along with parts of such tributary streams themselves.

This view I have for many years discredited; and the first thing which presents itself in opposition to it is, why, since the height attained in so many places by gravel *b'* shows that this part of England was submerged far above these gravel-patches, so vast a fluviatile denudation should have occurred in this region, when the corresponding area north of the Thames shows nothing of the kind? Why, for instance, should the river-valleys of East Anglia have undergone no appreciable denudation since the ice of the Chalky Clay deserted them, while those of the Weald during the same time have undergone so vast an excavation? The section of Prof. Hughes's which I have reproduced (p. 678) shows no denudation of the Hertfordshire valleys since the Chalky Clay plunged into them (as it did in all the valleys of the area occupied by it); and figs. VI., VII., and XL. show the same for the valleys of Essex, as do figs. I., VIII., and IX. for the valleys of Suffolk and Norfolk.

The next thing in reference to this view that demands inquiry is, What is there in these gravels to indicate a fluviatile origin, and to rebut the contrary inference afforded by the extraneous débris present in them, to explain which such large postulates have been demanded?

No fluviatile shells, so far as I know, have been found in them, though such have been found in the gravels skirting the rivers at low elevations, which are admitted to be of fluviatile origin. All that has been found in the former in the shape of organic remains are those of mammalia (and these, so far as I know, only in one case, viz. at Marden, and there in a bouldered condition) and some palæolithic implements *. The latter have occurred in the inlet gravel of the

* The implements have occurred in the gravels of the Plaxtole rivulet valley in the exact centre of Sheet 6. Some of these gravels according to Mr. Smith (in vol. xxiv. of 'Nature,' p. 30) are 400 feet above O. D., and about 100 above the rivulet. The gravels thus containing implements extend along the rivulet valley from 400 feet at Ingtham to 200 at Dunks Green, a distance of only four miles. Such of this gravel as is on the Weald clay contains subangular flints and Lower-Tertiary pebbles, though the source of the rivulet is in the Neocomian.

Bournemouth plateau, and in gravel *f* at Dartford Heath, and mammalian remains in the gravel *c* beneath the Chalky Clay at Birkett Wood in the Colne channel, as well as in the mud deposit at Selsey, rich in marine shells, described in Stage VI.; but neither implements nor mammalian remains are any more evidence of a fluviatile or freshwater origin for the gravel containing them than are the subangular flints with which they are associated, for the base of the Red Crag abounds with such remains (and much in the condition too in which bones are found generally in gravels), and I myself found part of a mammalian humerus associated with the marine Lamellibranchiata, in the position in which these lived with valves united, in the pebbly sand, *b 1*, beneath the Cromer Till at Weybourne. On the other hand, the absence of marine shells is (with the exception of the seam in the upper part of *c*, which is confined to East Anglia, and due to the ploughing-out of an older bed by the Chalky-Clay ice in its advance)* the character of all the gravel, whether *b'*, *c*, *e*, or *f*, everywhere except in the North-west of England and the Severn valley; and even there, save in the case where they occur in clay seams intercalated in the gravel, as at Ironbridge, these shells, though synchronous, are much worn and evidently transported; gravel bottoms apparently being adverse to the life of testaceous Mollusca.

These high patches of gravel within the valley of the Medway and other Weald rivers, including that of the Tillingbourne valley, appear to me, save so far as they may be due to the rise of the water-line in consequence of the depression traced in Stage VI., to have accumulated either under the sea, or in estuaries as the sea was invading or was retiring from the land; and though the accumulation may have begun as the valleys which its remnants occupy became engulphed by the submergence, it had not terminated at the time represented in Map 2 and its continuation. Inasmuch, however, as the fresh water necessarily followed the salt as this retired, fluviatile beds may be present in these valleys at that level (high in comparison with that of the present streams) at which the fresh water thus following was at that time maintained by the retiring sea, without indicating any great excavation of the valley in which they occur.

* I have in the first part of this memoir (p. 484) explained this exceptional occurrence of shells in the gravel *c*. The introduction of mammalian remains into the *lower part* of the Tillingbourne gravel from the destruction of freshwater beds of antecedent age, as the sea was gaining on the land during submergence, would be similar to the way in which mammalian remains have got into the Red Crag; and the extremely erroneous inferences which have from such remains in the Crag been drawn as to the Mammalia that were coeval with the Red Crag may, *toties quoties*, apply to these remains in beds of Glacial age. See on the same question the remarks as to this derivation in Siberia made in describing Stage VII.

Part 2.—The Post-glacial Period, comprising the *Cyrena-fluminalis* Formation, and the Minor Glaciation.

Stage VI. *The* Cyrena-*formation.*

Under the conditions which I have traced, the valley of the Thames, after the parting from the Severn system by way of the Swillbrook had emerged, became a sea-loch open to the North Sea by way of its present mouth, and also open to the Weald by way of the low ground over the faulted part of the Chalk near Farnham. The partings of those drainage-systems of the Weald which are represented as covered by the sea in Map 2, being most of them equal *in actual elevation* to that of the Swillbrook, and even the lowest of them, which is that dividing the (Kentish) Stour from Romney marsh at about 150 feet, equal to it when taken in connexion with the westerly increment of depression, had, however, at this time all emerged. As the low ground of this faulted chalk emerged, the basin of the Thames became separated from the Weald, except to the extent of receiving drainage from thence as it now does by the Wey, Mole, and Darent; from which condition, as emergence proceeded, it passed to that of a river which mingled with the sea-water much to the east of the point at which it now does so, receiving probably as tributaries the rivers of North Kent and South Essex, though hardly, I think, those of Suffolk and Norfolk, which probably reached the sea independently, though much to the east of the present coast-line. This greater distance eastward of the river-discharge at the commencement of the *Cyrena*-formation was due (if we omit for the present that part of the problem which involves the general depression of England subsequent to the last stage traced in this memoir, and which has caused land-surfaces round our coast to become covered with salt water and marine silt and forest with marsh mud, and which has brought the salt water further up the Thames than we find any *certain* evidence of its having done during the re-submergence I am about to trace) to some little of the original westerly increment of depression not having been recovered; or, more properly speaking, to the present inclination not having been fully attained; for, during the Red Crag, South Essex and Kent probably extended far beyond their present limit, and most likely to Belgium *. It is important, in considering the volume of fresh water within the Thames valley during the stage under consideration, that this should be borne in mind, as well as the position occupied by the bottom of the river, as shown by the basement bed (No. 1) of

* Prof. Prestwich describes the gravel corresponding with the sand in which he has found the *Cyrena* at Oxford as occupying a level of from 20 to 25 feet above the river around Oxford. At Grays and Crayford the fossiliferous part of the *Cyrena*-sand (No. 3 of the sect.) reaches to about 50, which would show the difference in fall between there and Oxford to be about 25 feet less than now. As the Reindeer occurs in some of the Oxford gravel, the gravel *g* with Reindeer remains there is probably at the same level with the *Cyrena*-sand.

the *Cyrena*-formation at Grays in figs. XXI. and XXII.* In this connexion, too, the generally received theory of the cutting down of valleys by the rivers, which has been adopted to reconcile the evidences of the former width over which a river extended with the physical difficulty involved in the presence of so large a volume of fresh water in the valley, as these evidences would otherwise point to, should be dismissed from the mind; for we have clear evidence that, so far from these evidences in the Thames and East-Essex valleys being connected with a lowering of the valley by river-excavation accompanying an elevation of the land, they are connected with a rise of the river-level due to a general depression of the land and consequent rise of the sea-level.

From the same cause the Wash rivers, Cam, Great Ouse, Nen, and Welland, when, after the draining-off of the great volume of water caused by their being dammed up by the ice, these rivers came into existence, had a flatter fall, and mingled with the sea beyond our present shore; the sea-level on the *east side* of England being at this time below the present.

The channel and deposit of the Thames before this resubmergence occurred is shown by the bed of gravel (No. 1 of ϕ) at Grays, which is confined to the bottom of the river-channel which occupied the site of the Grays brickfields at the commencement of the stage under consideration (see figs. XXI. & XXII.); and its dimensions, even when we allow for the greater distance of the sea than now, are small. This river-channel became enlarged by the depression presently traced, so that the beds of the *Cyrena*-formation there which succeeded it, and are numbered 2, 3, and 4 in the figures, are mutually transgressive. At Grays there is a shelf of chalk between this original channel and the present river, so that the channel of the *Cyrena*-stage was different from that at present, and also from that which existed during the gravel g, which, so far as can be seen, appears to have coincided in the main with that of the present river, though in a more expanded state. The position of the original river-channel, I cannot doubt, was shifted by the disturbances subsequent to the *Cyrena*-formation presently examined. The lines of figs. XXI. and XXII. show the position of the *Cyrena*-formation relatively to the rivers Thames and Darent, as well as to the gravel (g) described in Stage VII.

Before tracing the distribution of this formation I may observe that, as has been long known, the freshwater parts of it have yielded the remains of a fauna, both mammalian and molluscan, that indicates a climate different from that which must have prevailed when the gravel g and the accumulations of most of the caverns were formed.

* I have taken the position of this bottom from the section of Mr. Tylor in vol. xxv. of the Journal, which in that respect agrees with my own observations; but, so far as the gravels f and g of these figures are concerned, my sections differ from his, that gentleman showing them as one, and (so far as I can follow his section) as wrapping the *Cyrena*-formation.

I cannot, however, make out what Mr. Tylor intends to represent by what he terms "the covering bed" or "covering gravel," unless it be the bed γ of this memoir.

Amongst the Mammalia, the presence of the Fallow Deer and the absence of the Reindeer have been cited as evidence of mild climate, and the presence of *Rhinoceros megarhinus* as evidence of perhaps the same kind; but more certainly (notwithstanding the alleged occurrence of the frozen carcase of this species in Siberia) of an antiquity greater than the cave-deposits. Among the Molluscan remains evidence more decisive is found; for of the three freshwater shells of this formation, one, *Cyrena fluminalis*, is not known living nearer to us than the Nile, and inhabits the rivers of Thibet and China, and two others, *Unio littoralis* and *Hydrobia marginata*, are not known living nearer to us than the South of France. The Musk-Ox cranium (which, judging from Prof. Dawkins's figure, seems to have occurred at Crayford in bed No. 2 of the formation) points in the other direction so far as it goes; and as the *Cyrena* lived during the Upper Crag (and even at the beginning of the sand *b 1*), it is probable that the climate of this Crag and of the *Cyrena*-formation did not much differ, though probably the latter was milder than the former.

In tracing the distribution of this formation as far as known, I commence with the recent discovery of it by Prof. Prestwich, in the form of a sand at Oxford, from 20 to 25 feet above the level of the Isis, more than 300 feet below that of the gravel *b'* on the hills around, and from 400 to 500 feet below the line of maximum submergence there. The spot is distant 24 miles from the water-parting of the Thames and Severn systems by way of the Evenlode, and 30 miles from that by way of the Cherwell; and the elevation of the sand yielding the shell is about 230 feet below the elevation of these partings. Prof. Prestwich, however, mentions that a single specimen was obtained years ago from a pit on the banks of the Cherwell, and nearer therefore to that parting. The occurrence of it at Erith, Crayford, Ilford, and Grays is too well known to need mention; and I believe that it has occurred near Southend, but have not verified such occurrence. Although at all these places below London the transgressive character of the successive beds of the formation is apparent, it is further to seaward, viz. at Clacton on the coast, in the south centre of Sheet 48, that we find the first distinct evidence of the depression to which this transgression is due having changed the fresh to salt water. At that place the freshwater part of this formation, abounding in valves (often joined) of *Unio littoralis*, associated only with other shells exclusively of freshwater habit, descends below the level of high-water on the sea-beach; but upwards in the Cliff section, this part changes gradually into a bed containing marine shells, along with which *Cyrena fluminalis* was found by Mr. O. Fisher (see bed ϕ 3 of fig. XXIV.).

In section 8 of the plate to a paper in the 'Geological Magazine' for 1866, p. 348, I first showed the position of the Clacton part of this formation relatively to the gravel *f* in the Clacton and Holland Cliff; but I have now given fig. XXVII. to show not only this, but also the position of *f* relatively to the gravel at Tolleshunt; the relation of which again is in fig. VII. (in the plate to the first part of this memoir) shown relatively to the gravels *c* and *b'*. Mr. Fisher's section

of Clacton Cliff in the 'Geological Magazine' for 1868, p. 214, is substantially the same as that subsequent thereto which is in the Geological Survey memoir for quarter-sheet 48 S.W.; but I have reduced fig. XXIV. from the figure in that memoir.

On the opposite side of the Thames estuary, at Chislet in the valley of the Kentish Stour (north centre of Sheet 3), the remains of the *Cyrena* are described by Prof. Prestwich * as occurring with other freshwater shells in a bed of sand from 20 to 30 feet above O. D., intermixed with valves of a marine Cirriped, and with (according to Prof. T. R. Jones) a brackish-water Entomostracan found in the *Cyrena*-formation at Grays, and a brackish-water Foraminifer. This sand at Chislet is described by Prof. Prestwich as overlain by a mass of gravel, rubble, and brickearth, from 3 to 8 feet thick, which may correspond to the bed No. 4 of Clacton, or be the terrestrial formation γ described in Stage VII. There is thus at about equidistant points from Grays evidence of the propinquity of the sea towards the latter part of the formation on the south side of the Thames estuary, and of its actual presence on the north side.

At Grays the gravel-bed No. 1, forming the basement part of the formation, is overlain and overlapped by laminated brickearth with sandy seams (bed 2), and this again by a considerable thickness of false-bedded yellow sand (bed 3), into which it passes by alternations of either bed, and in the lower part of which, as well as in bed 2, the *Cyrena* abounds in association with freshwater shells only †; but the change to this sand, and the false-bedded character of it at Grays, seem to show that tidal action in a decided form extended now, by reason of the incressing depression, up to that place. Being not only some miles higher up, but also apparently the deposit of a tributary of the Thames, the division of this sand No. 3 from the laminated brickearth No. 2 is less marked, and the sand of less thickness, in the Crayford and Dartford-heath portions of the formation, shown in figs. XXI. and XXII., while I am not clear that No. 4 is present there, or whether what is represented as such in fig. XXI. may not be the bed γ described in the sequel; but at Ilford the sand No. 3 is very distinguishable from the brickearth No. 2. It is, however, but little false-bedded, and contains, so far as I am aware, only freshwater organisms.

At Grays No. 4 reaches a higher elevation than No. 3, and is proportionately more transgressive; so that I have found patches of it on the chalk of Stifford quarry a mile to the north of fig. XXIII., and on the gravel *f* opposite the "Inn" at Stifford (at between 80 and 90 feet above O. D.), which have escaped the general denudation of this formation presently referred to, as I have found it on this gravel in various parts of Essex. On the top of the chalk-quarry shown in fig. XXIII. the transgression of No. 4 over No. 3 was, when I drew it in 1865, actually visible in section, the two occupying

* Quart. Journ. Geol. Soc. vol. xi. p. 111.

† Although *Unio tumidus* swarms at Grays, I could never find *U. littoralis* there. Sir Chas. Lyell, however, sent my father some specimens of it which he had found there many years ago.

a hollow in the Thanet Sand, which elsewhere in the quarry was overlain by the gravel *f*. The part of No. 3 which appears there is only the uppermost, which, so far as I know, is unfossiliferous. The elevation of this section is between 80 and 100 feet.

The *Cyrena*-formation appears to occur up the Lea valley at Stoke Newington, and to reach there the elevation of about 100 feet above O. D.; but the *Cyrena* itself has not been yet found there, so far as I know, nor do I know precisely up to what part of this elevation shells have occurred*. From the elevation which it there attains, however, it must have occupied the Lea valley for a long distance to the north of that place; and, as regards the Thames valley, the thick bed of brickearth which occurs at West Drayton, Slough, and other places in Sheet 7 (and which is shown in Map 3 as the *Cyrena*-formation) appears to me to be this bed No. 4, similarly transgressive, so that it there rests on the gravel *f*, reaching an elevation of 120 feet; and it is shown on the Geological-Survey map as overlapping the northern edge of *f*, and resting for a considerable distance on the London Clay (see for this also, Map 3, Pl. XXVI.). Between there and London, this bed (No. 4) appears to me to be represented at Acton, in fig. iv. of Col. Lane Fox (at page 456 of the 28th vol. of the Journal), by the brickearth with seams of sand, which in an adjoining section he describes as "passing gradually down into fine yellow sand without stones" (the elevation being 82 feet), that sand, which is gravelly in some places, being bed No. 3 of Grays, though only the remains of a fern, and no shells, occurred in it. The transgression is shown at Acton by this sand resting on the London Clay at an elevation which, relatively to the Thames level, corresponds with that reached by it at Grays; and the occurrence of a tree-trunk on the London-Clay surface at the base of the sand, shown in Col. Lane Fox's fig. iii., accords with that trangression; but beds 1 and 2, which were confined to lower elevations, have been removed to make place for the gravel *g*, described in Stage VII., which about Acton also passes up into brickearth, and is that distinguished by Col. Lane Fox as the gravel of the "medium and lower terrace."

This bed No. 4 occurs in many parts of the Thames valley, but not in thickness sufficient for its representation in Map 3, the scale of which only allows of the representation of the *Cyrena*-formation on it where some part of this is worked for bricks; and, as I have already said, probably both in the Geological-Survey map and in mine, some and perhaps much of what is shown as gravel *f* may be the sand No. 3. Judging from the greater thickness of No. 4 at Slough railway-cutting, it seems elsewhere to have been reduced by denudation during emergence; and in the smaller thickness thus resulting it rests on gravel *f*, in the railway ballast-pit at Chadwell Heath in Sheet 1, at between 60 and 70 feet elevation, and seems to form a thin surface-bed over much of the area between there and the line of fig. XXIX. It is worked for bricks over *f* between Southend and Prittlewell, and much of the country north of Southend, at elevations which, allowing for the fall of the valley, correspond with those higher up

* See, however, note at page 741.

it, viz. between 30 and 60 feet. Palæolithic implements have (either at Acton or Crayford) occurred in Nos. 1, 2, and 3.

Northwards along the eastern border of Essex, where the gravel *f* is shown extending, traces of No. 4 occur as far as Bradwell *, 12 miles W.S.W. of Clacton; but at Clacton it has changed to a loamy gravel, which, but for the Cliff-section showing it to be distinct from *f*, by the edge of bed No. 2 A of the *Cyrena*-formation being intercalated between them, might be confounded with *f* (see fig. XXIV.)†.

In England, south of the Thames, the *Cyrena* has not yet been detected either in marine or freshwater beds; but northwards as far as Yorkshire (irrespective of its presence in the Upper Crag, and the base of the sands *b 1*, where these are fossiliferous and fluvio-marine, as in the Bure valley) it has occurred in many places in beds of the Stage under consideration. Taking them in their order northwards from Clacton, we find it in a bed of peaty sandy clay at Stutton (centre of Sheet 48) in the valley of the Stour estuary, which divides Essex from Suffolk, at the edge and level of the salt water which fills this estuary; the valley in which this bed occurs being cut through the sands *b 1* and gravel *c*, and having formed one of the fiords by which, during the latter part of Stage III., the ice of the Chalky Clay issued to the sea. So far as I am aware (and my father collected at one time extensively from it) no marine shell has occurred in the bed here; but the *Cyrena* specimens are of large size, with valves united, and associated with many species of freshwater and land Mollusca. In the extreme north-east of the same sheet, however, in the valley of the Butley Creek (another of the issues of the ice of the Chalky Clay at the close of that formation in East Anglia), the *Cyrena* also occurs in a bed overlying the Coralline Crag in the "Broom" and "Gomer" pits at Gedgrave. Here it was found by my father associated with marine shells, which, from his remarks ‡, I inferred were merely derivatives from the Crag. Messrs. A. and R. Bell, however, inform me that though some of the shells in this bed (such as *Trochus subexcavatus* and *Murex tortuosus*) are, no doubt, derivative, others, which are of living species, are unlike the Crag shells in mineral condition, being but very slightly fossilized, and that one of them (*Buccinum undatum*) is not the thin form of the Crag, but the thick shell now living on our present coast. I have found also in my father's cabinet some specimens of *Trochus cinerarius* marked as "from the bed over the Red Crag of the pit near the Oyster Inn, Butley;" and these retain much of their colour, and are, like the shells of the Nar valley and Selsea beds, but slightly fossilized §. My father also (Crag Moll. vol. i. p. 109) speaks of

* At Currys Mill, Bradwell, I found 7 feet of it placed vertically beside the gravel *f*, seemingly let down by a small fault, and so saved from the denudation which had there removed this bed from the general surface of the gravel *f*.

† At Clacton there seems to have been a denudation of the edge of No. 3 before No. 4 was deposited.

‡ See 'Crag Mollusca,' vol. i. p. 109, and vol. ii. p. 105.

§ Mr. A. Bell informs me that he obtained these specimens of *Trochus* from the patch of clay marked with an asterisk shown by him in his section of this pit at page 451 of the Geol. Mag. for 1871, and gave them to my father.

having obtained, from the bed over the Coralline Crag which yielded him the *Cyrena* in association with marine shells, specimens of *Hydrobia ulvæ* in this imperfectly fossilized condition, so that I can hardly doubt that the sea entered the Butley-Creek valley during the stage under consideration, and from the elevation at which this bed occurs, up to the height at least of 40 feet above its present level. North of this, along the eastern side of East Anglia, no further trace of this shell (save in the Crag and in the sand *b1*) has yet been detected; and but for what seems to occur in the Butley valley, I should have inferred that the sea at this time did not enter the valleys of the Suffolk and Norfolk coast: but at Barnwell on the Cam (slightly to the south-west of the centre of Sheet 51) it occurs in a bed, the top of which is about 45 feet above O. D., associated with land and freshwater mollusca only. To the north of this bed, and distributed over the north centre of Sheet 51, the centre and west of Sheet 65, and the east of Sheet 64*, there occur patches of gravel rising as very low eminences out of the level of the Fen, in some of which marine molluscan remains occur numerously; and on the east side of the Wash, in Sheet 69, the same formation is continued by a brick-clay in the valley of the Nar, and a gravel at Hunstanton, all yielding numerous remains of marine mollusca, all of living species. This formation, in its marine condition in Sheets 51, 65, and the Nar valley, seems not to reach elevations of more than 30 feet above O. D., thus corresponding with the freshwater part at Barnwell at about 45; and though the *Cyrena* has not been found in it at Hunstanton or in the Nar valley, my friend Mr. Harmer found many specimens of that shell (some of which I have) in association with the marine shells in this gravel at March, in Sheet 65, just as they are in the Yorkshire part of the formation at Kelsea Hill, in Sheet 86.

At Overton (or Orton) on the Nen, in Sheet 64, where this gravel appears to be at an elevation of about 20 feet above the Nen, and 40 above O. D., Mr. Trimmer † found *Ostrea edulis* and *Cardium edule* in it, in association with freshwater shells; but Prof. Seeley ‡ states that the fluvio-marine gravel here is underlain by clay containing freshwater shells only, thus presenting the same evidence of change from fresh to salt water by depression as is furnished by Clacton. The strong broken line on Map 5, indicating the

* For the distribution of this gravel in Sheets 51, 65, and 69, see Seeley in vol. xxii. of the Journal, p. 470. For Nar brickearth, see Rose in Phil. Mag. for 1836, and Geol. Mag. for 1865, p. 8. For the Mollusca of both, see Tabular list in 1st Supplement to 'Crag Mollusca,' Palæontographical Society volume for 1873, the Fen gravel being under the heading of "March gravel," and in same table is a column with the Mollusca from the Yorkshire part of the formation ("Kelsea Hill") and from Hunstanton.

† Quart. Journ. Geol. Soc. vol. x. p. 345.

‡ *Ibid.* vol. xxii. p. 474. Mr. Trimmer's section shows the freshwater bed as underlain by gravel with marine shells; but as he states that this rested on the authority of the workmen, and he himself found the marine shells at 7 feet from the surface, which, on the scale of his figure, would be above the part with freshwater shells, and the mammalian remains were in the lower part, it is likely that this was a mistake, and that Prof. Seeley's statement is correct.

limit of the submergence of the Stage I am examining, defines the limit of this marine and fluvio-marine part of the formation in Sheets 51, 64, 65, and 69; and this line is carried thence northwards in accordance with the evidence of increasing depression in that direction, which the limit in elevation reached by the formation in Sheets 85, 86, and 94 furnishes.

I have no certain knowledge (beyond the presence of gravel, which, so far as I know, is unfossiliferous) of any thing which can be identified with this formation within the line thus carried northwards till the north of Sheet 86 is reached, where, on the north of the Humber, marine gravel with the *Cyrena* occurs at Kelsea Hill and at Paull (Paghill) Cliff, both a few miles east of Hull: but on the Lincolnshire side of the Humber, at Kirmington (just where the broken line extending northwards a few miles from the Lincolnshire coast makes a short westerly deflection in the north of Sheet 86 of Map 5), Mr. Rome and I found united valves of the marine and estuarine shells *Scrobicularia piperata* and *Mytilus edulis* imbedded in a brick-clay, from which we learnt that mammalian remains had been also obtained. Although the *Cyrena* was not with these, I feel little doubt of this clay being a part of the formation, and corresponding to the gravel with *Cyrena* in Holderness in the same way that the brick-clay of the Nar (in which also no trace of the *Cyrena* has been detected) corresponds to the gravel with *Cyrena* at March. Its elevation appears to be somewhere between 80 and 90 feet.

The section of this *Cyrena*-gravel afforded by the Kelsea Hill ballast-pit near Hedon Station, when I drew it in 1867, is shown at page 713; and the section at one part being more than 30 feet high, and the *Cyrena*-valves present nearly to the top, it shows this gravel here to reach the elevation of about 55 feet above O. D. These valves are here also in association with marine shells only; and, as is the case at March, none of the valves are joined, as they frequently are in the freshwater parts of the formation, thus showing that they have been transported by river-floods into the sea-bed. Along the Holderness coast-section, where it is shown in figs. XLVI. to XLIX. by bed Φ, the greatest elevation of this gravel seems to be from 75 to 80 feet above the beach, or say 90 above O. D., dying out against the highest parts of the Purple Clay, D, which seems to have formed low islets in this gravel-sea. I am not, however, aware of any shells having been obtained from it in the Holderness Cliff.

At Hessle, where it is also unfossiliferous, it rests upon a clay-pan which is strongly ripple-marked (see fig. XLV.) and which overlies rubble with mammalian remains that rests on the Chalk. Here, again, we have good evidence of the gravel having been accumulated under a redepression, which first caused a land-surface to become covered with mud, which was left dry and ripple-marked at low water, and eventually submerged it, so as to allow the sand and gravel, Φ, laid down on this, to be deposited up to the level it reaches in fig. XLIV.

I have continued the broken line of Map 5 northwards on the

west of the Wold through Sheet 93 into 96, because the great plain of the vale of York is overspread with sand and gravel corresponding in elevation to this, and which extends to the western foot of the Wold. I am not aware whether shells have occurred in it in this vale; but where it is here overlain by the clay of the minor glaciation it has, according to Mr. Dakyns (vol. xxviii. of the Journal, p. 382), yielded mammalian remains. The upper limit of this seems to be somewhere about 100 feet, and the sand and gravel itself to die out *beneath* the clay of the minor glaciation, Γ, against the parting between the drainage to the Tees and that to the Humber. Near York it passes under this clay, and so continues northwards in the direction of this parting; but over the eastern side of the vale, between York and the Wold, it seems to be mostly uncovered by this clay. The gravel at corresponding elevation in the vale of Pickering appears to be of the same age, the sea having either overflowed this by entering from the vale of York through the gorge by which the Derwent flows outward from this Pickering vale, or by raising the water-level within this vale caused the Derwent to expand over it: but no trace of this gravel appears along the Yorkshire coast section, north of that shown in fig. XLIX., until the mouth of the Tees valley in Sheet 103 is reached *. Up that valley, however, sand and gravel corresponding to this which I have been tracing extends, rising to corresponding elevations on that side of the parting between the Tees and Humber drainage that the gravel of the Vale of York attains on the other, and similarly passing under the clay of the minor glaciation, though often uncovered by it; and this, I understand, has yielded shells. Throughout both the Vale of York and that of the Tees this gravel rests on Glacial Clay, which in the latter varies in character, part of it consisting of laminated clay used for brick-making, which probably belongs to the earlier part of the major glaciation when the ice had not been deflected, and the rest being the purple clay, D, both of these vales having been buried in ice throughout that glaciation.

Northwards from this through Durham and Northumberland, from the information furnished to me by Mr. W. Topley, of the Geological Survey, I have learnt that a sand and gravel occurs in the preglacial valleys of which the broken line in Sheets 105 and 109 of Map 5 follows the direction; and this, which rests on a Lower Clay, is overlain by the clay of the minor glaciation, which, where it passes over the edge of the gravel, so as to rest directly on the Lower Clay, is not easily distinguished, though as a rule it is, as is the case in the north-west of England, much more sparsely supplied with boulders (and these for the most part of smaller size) than is the case with the Lower Clay.

* This I state, however, on my own personal examination, only as far north as Scarborough; and whether any sand and gravel referable to that which I am describing occurs in the small valleys that open seawards from the eastern moorlands, I am unable to say. Some lenticular beds of gravel of small extent occur *in and under* the Purple Clay along this coast-section, which lead me to the opinion, expressed *ante*, that the Purple Clay, though terminating under errestrial conditions, began by submarine extrusion.

I am not aware of any evidence to prove that in the vales of York and Tees this gravel originated in a redepression; but, on the other hand, I know of nothing to suggest that the redepression, of which in connexion with this formation we get such clear evidence from the Thames to the Humber, did not extend to these parts of England also.

The Upper Clay of Cheshire, Lancashire, and Cumberland, which in Stage VII. I refer to the minor glaciation, and connect with that thus overlying the *Cyrena*-formation in Yorkshire, is in most parts of the lower ground of the north-west of England separated from the clay of the major glaciation by sand and gravel, corresponding to that of the *Cyrena*-formation of the eastern side of England; and this contains marine mollusca. Inasmuch, however, as the sand and gravel which (corresponding to that of the east shown under the letters *e* and *f*) was deposited after the retreat and disappearance of the ice of the major glaciation in the north-west contains molluscan remains, there appear to be no means of distinguishing the one from the other; and indeed, whether the redrepression extended to that part of England or not, the sea from the original great increment of depression in that direction probably continued to cover the lower elevations there; so that the redepression, if it extended to that part, would, owing to the abrupt way in which the plain of Cheshire and south-west Lancashire is bounded by the mountain-region, but very little enlarge the area thus remaining sea-covered. I have not therefore attempted to delineate by a line on Map 5 the limit of the submergence of the north-west of England during the *Cyrena*-formation, as I have done that of the north-east; but the area which is shaded with very fine dots in that map to indicate the moraine of the minor glaciation there can differ, I think, but little from this limit also.

As the clay of the minor glaciation, or Upper Clay, in the north-west (G′ of fig. LIII.), contains marine shells which seem to have been introduced in a similar way to those found in the clay of the major glaciation of that part of England (viz., by being dropped over the place where the moraine was undergoing extrusion beneath the sea by floe-ice bringing them from shore-lines), and as the corresponding clay of the north-east seems to be free from shells, and in other ways indicates that emergence from the depression I have just traced took place before it was laid upon the *Cyrena*-formation, the middle sand must reach to elevations as great as, and probably greater than, those to which the part of this Upper Clay of the north-west which contains shells reaches. My impression has been that in the shell-bearing condition this clay was confined to low levels, such as that of Blackpool Cliff, Mersey Docks, &c.; but Mr. Shone speaks of it as in this condition reaching the elevation of 600 feet at Macclesfield * and Arnfield.

If such really be the case, this would conflict considerably with

* Mr. Darbishire, in vol. ii. p. 41 of the Geol. Mag., calls the clay at Macclesfield "Lower Boulder Clay;" and as the bed on which the gravel at the cemetery which yielded him the shells he there describes from thence rests, he says, at 600 feet elevation, on clay, I presume that this must be the Lower instead of the Upper Clay.

the features in the east; for not only would it show an emergence of near 600 feet during the formation of that clay (the bed H of fig. LII., and the general distribution of the beds which succeed the upper clay in Lancashire showing that at its close the north-west had emerged within 20 or 25 feet of its present level), but if the evidences of land-surface beneath the middle sand which have been offered by geologists are reliable (of which I am not satisfied, however), it would show a previous *re*submergence to such an extent as to have again brought the north of England to an insular state, altogether separated from the south, for the water-parting between the Trent and Weaver systems is below 400 feet. I therefore think it probable that the cases mentioned by Mr. Shone must be those of the Lower Clay, in which some local division by a sand intercalation gives rise to the idea that the Upper Clay is present.

As regards the evidences of *re*depression in the north-west, it does not appear to me that those at Oldham offered by Mr. Hollingsworth in the 37th volume of the 'Journal,' p. 713, are sufficiently clear to justify my quoting them in support of this redepression; but Mr. Mackintosh informs me that the middle sand of the north-west is underlain by peat-beds near Crewe, at an elevation of between 150 and 200 feet. This would well agree with the evidences of resubmergence in the north-east, because it is probable that the very great increment in that direction of the original submergence described in Stage II. may have left the north-west still submerged at low levels when the depression of the stage I am now examining commenced; but Mr. Kendall, in the same volume (p. 38), gives several instances of beds of peat reached in borings in West Cumberland and North Lancashire, which, if connected with this redepression, would, as they occur beneath the present sea-level, indicate a complete emergence of the north-west previous to this stage. They, however, appear to me, from his maps and figures, to be all posterior to the Upper Clay, except the instance at Lindal, which seems to occur beneath near 100 feet of glacial clay, and to occupy an elevation of about 150 feet, thus agreeing with Crewe. I, however, agree with Mr. Kendall that we cannot be sure that this may not be due to transport during the major glaciation, rather than evidence of a land-surface *in situ*; for I have seen beds of peat some feet in thickness and of considerable length interstratified in the marine Till of Cromer; and the 100 feet of clay which overlies it is by no means consonant with the normal thickness of the Upper Clay in Lancashire.

Having now traced the redepression of the east side of England as having brought the sea-level in Suffolk to between 40 and 50 feet, and in Essex to at least 30 feet above the present, and in the country around the Wash to a similar elevation, from whence northwards the depression increased so as to bring this level up to nearly 100 feet, the question presents itself, how is the volume of water which under such circumstances occupied the Thames valley reconcilable with this, if such water was fresh? In that connexion I would first observe that, so far as I am aware, there is

nothing in bed ϕ 4 in this valley to indicate that the water at the time of its accumulation was fresh,—at any rate perennially fresh; and it is this bed only which from the elevation it attains offers any indication of a volume of water having occupied the Thames valley very much in excess of that at the present day; for if we compare the height reached by that part of ϕ 3 at Grays which contains shells, with the bottom of the *Cyrena*-river there, shown in figs. XXI. and XXII., the probable volume would not exceed that of the present river at Northfleet, where, when my father was a sailor, fresh water for the China voyage was taken in from the Thames itself; while the flatness of the fall, and the greater distance of the sea-water from Grays during the formation of ϕ 2 than it now is from Northfleet, which the features of the Clacton section show, seem to me to remove all difficulty in this question, so far as beds 1, 2, and the lower part of 3, at Grays, Erith, Crayford, and Ilford, are concerned. As regards ϕ 4, and the upper part of ϕ 3, if fluviatile shells have occurred in them, the fact has not come to my knowledge, nor should I, when the great flooding of the country at that time is considered, regard it, if it did, as a difficulty *. The bed ϕ 4 at Clacton is unfossiliferous; but from its transgressive position, and its evident succession by increasing depression to the bed ϕ 3 there, with its marine or estuarine shells (notwithstanding that some denudation of the edge of ϕ 3 seems to have occurred during this movement), we cannot question its having been due to this redepression. The deposit, however, changes from the clay and sandy loam of ϕ 2 and 3 to gravel with which loam is intermixed; and this seems to me to conspire, with the form of brickearth with bands of race which ϕ 4 assumes within the present Thames valley, to show that the later part of this depression was accompanied by a refrigeration of climate consequent on the approach of the minor glaciation described in Stage VII. This approach, as well as the wane of that glaciation, seems to have been accompanied by great flooding of the land; for the gravel *g*, which accumulated during that stage, passes up into brickearth in a similar way to that in which ϕ 3 of the *Cyrena*-formation does; and other phenomena described in that stage point to this flooding having occurred at the close of this glaciation. If this was the case when the *Cyrena*-depression was extending the sea-water up the eastern valleys, the effect might have been to render that water uninhabitable by mollusca, whether marine or freshwater. Something evidently caused the disappearance of both kinds of mollusca at Clacton before bed 4 accumulated there; and the mixture of loam with the gravel of that bed is suggestive of freshets filling the rivers and estuaries with a great quantity of mud, which, in the more seaward position of Clacton, was intermixed with a large quantity of stones by coast-ice from shores formed of gravels *c* and *f*, but which,

* Prof. Morris, in a notice of the Grays brick-pits in the Geol. Mag. for 1867, p. 63, speaks of the "brown clay" over the false-bedded sand ϕ 3, which I call ϕ 4, as yielding no fossils; and he doubts the fluviatile origin of both that and part of the sands it rests on. See, however, note at page 741.

higher up the Thames valley, was precipitated so much more profusely as to form the brickearth which there represents no. 4, and in which stones are in very subordinate proportion.

This depression necessarily raised the water-line of all the rivers; and the effect of it appears to me to be shown by the gravel of the Wey, at Peasemarsh (near Guildford in Sheet 8), and that near Dieppe on the French coast overlying a bed of peat as described by Mr. Godwin-Austen in the 11th volume of the 'Journal,' p. 112; and in the upper part of the Thames system the river-gravel of the present stage must generally be undistinguishable from *g*, because the rise of the land during Stage VII. (in a pause of which the gravel *g* and the shingle at the foot of the buried cliffs of the south were formed) brought the water-line back again to the same level, or nearly so, as that at which bed 3 of the *Cyrena*-formation *began* to accumulate. We see this by the features of the Grays and Crayford sections (figs. XXI. and XXXII.), and by that of the Ilford section (fig. XXV.) more clearly still; for there, in the Uphall field, the gravel *g* overlies the *Cyrena*-beds 2 and 3, which had in the interval been disturbed and denuded, so that this gravel spreads over their inclined edges, while the London-road field (fig. XXVI.), being at a higher level than the Uphall, and than that to which gravel *g* attains east of London, shows the *Cyrena*-formation not covered by that gravel but by the coeval formation γ instead. If it should chance that reindeer-remains were found in the gravel *g* in the Uphall field, or in the bed γ of the London-road field, the discovery would probably be announced as one in the *Cyrena*-formation; whereas it would be in one separated from that by the latter part of the time involved in the depression which I have traced, by part of that reelevation which, in Stage VII., I am about to trace, and by the change in climate caused by the incoming of the minor glaciation; and it is in this way, I apprehend, until the contrary be clearly shown, that the gravel at Oxford, of which Prof. Prestwich speaks as containing Reindeer-remains at the same elevation above the river as that which has yielded the *Cyrena*, may be thus quite distinct from it *. Perhaps, also, some of the patches of gravel in the valleys of the Wealden area, that are at higher elevations than the general outspread near the rivers which seems to belong to Stage VII., may be remnants of the deposits of these rivers when their water-line was raised by the depression of the *Cyrena*-formation.

As regards the evidences of this redepression southwards from the Thames, they are, though more obscure, I think to be traced.

A range of sections showing old cliffs with beaches at their foot, and buried under the accumulations described in Stage VII., have occurred on both the French and English sides of the British Channel, and been described by geologists in the Society's 'Journal' and elsewhere; viz. at Sangatte †, at Brighton ‡, at the Isle of Wight

* See, however, note at page 741.
† By Prestwich, in vol. vii. p. 274, and vol. xxi. p. 441.
‡ By Murchison, in vol. vii. p. 365, and A. Tylor, in vol. xxv. p. 79.

Foreland*, at Portland †, and at Sili Bay in South Wales ‡. Gravel and sand is spread over the low ground which, beginning at Brighton, extends westwards over a gradually widening area between the coast and the South Downs, in Sheet 9, into apparent inosculation with the gravel at a nearly corresponding level which occurs through the south of Sheets 11 and 15, and to which I have already adverted in connexion with the Bournemouth plateau in tracing the emergence from the great depression (see *antè*, p. 688). This sand, in which he found marine shells, an Echinoderm, a Cirriped, and some Foraminifera, all of species living in the British Channel, Mr. Prestwich has regarded as of the age of the Brighton beach §; but as the places where he describes it, viz. Avisford and Bourne Common (from the former of which he obtained these organic remains), are respectively, he says, at 100 and 140 feet elevation above O. D., and the Brighton beach is only from 10 to 12 feet above the existing one ||, I fail to see this, especially as these places are about midway between that beach and the one at the Foreland or Eastern end of the Isle of Wight, described by Mr. Codrington (and shown in fig. LV., copied from his figure), where the top of the shingle at the cliffs' base is at only 60 feet above O. D. ¶. All these beaches appear to me to have been formed during a pause in the rise from the depression I have been tracing, when the land became stationary, and the gravel *g* described in Stage VII. accumulated; for it seems to me an impossibility that cliffs in yielding strata, such as the chalk of the Brighton one, or the marl of the Foreland one, can survive a submergence—the action of the sea during which must inevitably be to plane them off; while during emergence cliffs cannot form, because the sea is receding. It is therefore only at the upper limit of a submergence, or during a stationary period, that such cliffs can be formed; and these, unless protected (as the cliffs in question have been by becoming buried under a peculiar formation), would be soon obliterated by atmospheric agency. Thus, I think, we may conclude that the South of England has never been submerged since the Brighton and Foreland beaches were formed, unless it were after they received the envelope of materials under which they are buried, which is not applicable to the present contention, or even suggested.

It was before these beaches came into existence that the Avisford and Bourne-Common sands were, in my opinion, accumulated up to elevations of 140 feet; and these appear to me to indicate the submergence of the South Coast during the *Cyrena*-formation, though I cannot point to any actual evidence of *re*-submergence connected with them, or to the presence of the *Cyrena* in them.

* By Codrington, in vol. xxvi. p. 541, of whose section fig. LV. is a copy.

† By Prestwich, in vol. xxxi. p. 36.

‡ By same, in Brit. Association Reports for 1880, p. 581.

§ Quart. Journ. Geol. Soc. vol. xv. p. 219.

|| *Ibid.* p. 220, and vol. xxviii. p. 38.

¶ Avisford is in the south-centre of Sheet 9, 20 miles west of Brighton, and 23 E.N.E. of the Isle of Wight Foreland; and Bourne Common is due west of this, and on the division of Sheets 9 and 10, 33 miles west of Brighton and 14 north-east of the Foreland.

The same movement of depression, however, carried the salt water on the French side up the Somme valley as far as Abbeville, and gave rise to the sand and gravel with marine shells in which the *Cyrena* occurs at Menchecourt, the upper part of which, according to Prof. Prestwich's sections in the 'Philosophical Transactions' for 1864, seems to be about 85, and the lower about 35 feet above O. D.

M. Rutot refers this sand and gravel to a depression of the Somme valley causing a reentry of the sea there*, and states that it is overlain by clayey bands containing in their midst sand with freshwater shells only (being the reverse of the feature disclosed by Clacton); and he attributes this to the reelevation of the valley; but inasmuch as an elevation of the land would convert the central or deeper part of a saltwater estuary, rather than the shallower sides of it, into a freshwater river, and it is on the sloping sides of the Somme valley that the bed thus passing up from a salt to a freshwater condition occurs, it seems clear to me that it could only have arisen from that augmentation in the volume of the fresh water which I have traced in the case of the *Cyrena*-formation in the Thames valley. It is the gravel occupying the centre of the Somme valley, beneath the modern peat, to which the reelevation gave rise, that corresponds, in my view, most nearly to *g* of my figures. This elevation brought the sea-level down to that of the beaches of the buried cliffs; but the gravel beneath the peat descends below this level at Menchecourt, because it occupies the centre of the old river-bottom.

On the shore at Selsea in Sussex, 10 miles south, and seaward of the line of submergence thus indicated by the Avisford and Bourne-Common sand and shingle, and midway between those two places, but at full 120 feet less elevation (for it is washed by the sea at high water), occurs a bed of mud rich in marine mollusca, with which mammalian remains have also occurred. This bed is described by Mr. Godwin-Austen † as overlain by the clayey gravel with great blocks of hypersthene rock described in Stage VII. as a formation of the minor glaciation, and shown in fig. XLII. by the letter G; and a list of the mollusca from it have been given by him and by Mr. Dixon ‡, to which Mr. Alfred Bell has made many additions §. The whole form a remarkable group, showing on the one hand, by

* Bulletin de la Société Royale Malacologique de Belgique for 1881. Prof. Prestwich also, in his memoir in the Phil. Trans. for 1864 (p. 284), shows the gravel with *Cyrena* and marine shells at Menchecourt as underlain by sandy marl containing chiefly land and freshwater shells. This indicates that a change of the ancient Somme from a freshwater to a marine condition took place by the depression which I have traced, just as Clacton does for the ancient Thames system.

† Quart. Journ. Geol. Soc. vol. xiii. p. 40.

‡ Geology of Sussex, 1st edit. p. 13.

§ These, according to a list furnished by Mr. Bell to my late father, in my possession, are 25 in number, making with the species mentioned by Dixon and Godwin-Austen, and one by S. P. Woodward (in MS.), a total of 79, after deducting six repeated synonymously, there being some obsolete names in Dixon's list. The whole 79 are species living on the south coast of England, except the two mentioned in the text as confined to the Lusitanian coast.

the presence of two species, *Lutraria rugosa* and *Pecten polymorphus* (which are Lusitanian species not now ranging into British seas), and by the general character of the shells, a somewhat warmer sea than now washes the Sussex coast; and on the other, by the absence of any species not known as living in the British or Lusitanian seas, a much more modern origin than the Upper Crag, or even the lower part of the sand *b 1*, or the Bridlington or Dimlington beds; all of which do contain Crag species not known as living; while the absence of such species as *Astarte borealis* (*arctica*) found in the gravel *b'*, and other Arctic species found in the clay of the great glaciation, where that was of submarine extrusion, equally remove the bed from any connexion with the period of the major glaciation. It appears to me that this bed coincides nearly with the base of the *Cyrena*-formation in the Thames valley, and was formed at the beginning of the redepression under which that formation took place, having accumulated before the invading sea reached the Avisford and Bourne-Common level; the Lusitanian character of the mollusca, which distinguishes it from what I regard as the nearly synchronous gravel of the Wash country (the mollusca of which, though all living on this side of the Atlantic, comprise four species confined to the sea north of the British Isles *), being due to the intervention of the isthmus between Kent and France, which was then in existence.

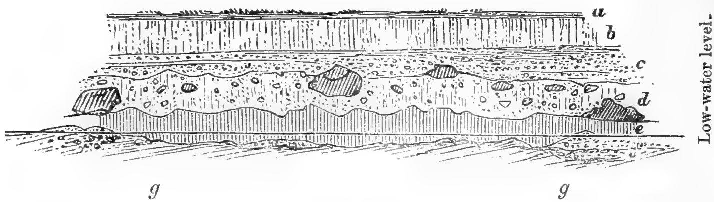
Upon the effect which such an isthmus would produce in this way, I need not enlarge, as it is obvious to geologists, and its existence subsequently to the great glaciation is generally conceded: but the few shells and other organisms found by Mr. Prestwich in the sands at 100 feet elevation at Avisford, furnish no indication of that warmer sea which the Selsea shells do; and they, in my view, accumulated at the culmination of the depression that preceded the minor glaciation, and when the Selsea bed had twenty fathoms water over it, the deposit corresponding to the sand of Avisford which accumulated there having been removed by the waves during emergence. The approach of the minor glaciation was then refrigerating both sea and land; but whether the disappearance of the southern shells from the Sussex coast was due to this refrigeration alone, or to its being accompanied by the letting in of the North Sea by the submergence of the isthmus, may be left to conjecture, though the character of the existing English fauna, especially the

* The gravel of Kelsea Hill has yielded only two of these shells, that of March all four, and the Nar brickearth only one. The rest of the shells from all the marine beds in Norfolk, Cambridgeshire, and Yorkshire, which I refer to the *Cyrena*-formation, still live in British seas. Three of these four, viz. *Pleurotoma pyramidalis*, *Astarte borealis*, and *Tellina lata* (*calcarea*), are given in Mr. Shone's list, p. 394 of vol. xxiv. of the Quart. Journ., as occurring in the upper boulder-clay of the north-west; the rest of these shells in that clay, except the Arctic species *Natica affinis* (*clausa*), still living in British seas. The fourth, *Trophon scalariformis*, he gives with *Astarte borealis* from the Middle sands of the north-west (the *Cyrena*-formation), in association with species all still living in British seas. Space does not allow me to give lists of the mollusca from the various beds examined in this memoir.

reptilian part of it, points rather to the insulation of England having taken place subsequently to the minor glaciation.

By permission of Mr. Godwin-Austen and of the Council, I here give the woodcut from his paper.

Cut iii.—*Diagram section showing the general relation of the Newer Tertiary deposits of the Sussex levels.*



a. Vegetable mould.		
b. Brickearth with small sharp splinters of flint, and occasionally old Tertiary pebbles, and the small seeds of some plant. This thickens towards the hills, and there contains *Helices* and *Succineæ*.	=	γ of my figures, and described in Stage VII.
c. Gravel, with occasional seams of sand and pebbles, and with marine shells. *d.* Yellow clayey gravel with granitic blocks, some of which are of very large dimensions, ranging up to masses of 20 tons' weight, and one being 27 feet in circumference.	=	G of my figures, and described in Stage VII.

e. The marine mud deposit with *Lutraria rugosa* &c. and mammalian remains.

f. "Lower Red gravel" = *f* of my figures. *g.* Older Tertiary strata.

Two things contribute to show that this Selsea bed (*e* of the diagram) was not due to the retiring sea of the great glaciation—one the presence of shells, the beds of that glaciation in Hampshire being destitute of them; and the other the fact stated by Mr. Godwin-Austen, and shown in his diagram section, that this bed is unconformable to the gravel of the Hampshire inlet, termed by him the "lower red gravel," and corresponding to *f* of my figures, of which I have traced the emergence.

This unconformity, if it do not prove redepression, is at any rate very consistent with it; and the presence of mammalian remains associated with the marine Mollusca in this bed is much more consistent with its accumulation when near to land, and covered by no great depth of water, than when the sea was more than twenty fathoms deep over it, and the shore at least nine miles to the north of it, as it must have been when the Bourne-Common and Avisford beds accumulated.

The position occupied by the group of beds in the foregoing diagram section relatively to the gravel of the great submergence and major glaciation, *b'*, *c*, *e*, and *f*, is shown in fig. XLII. of the plate, if the bed G in that figure be (for this purpose) taken as indicating the whole group.

The sands which are thus more or less fossiliferous in the littoral part of Sussex, in Sheet 9, and which may perhaps be represented by the bed of shingle on Portsdown Hill (in the south-east of Sheet 11) at the elevation of 125 feet, described by Prof. Prestwich in the 28th vol. of the Journal, do not seem recognizable in the corresponding part of Hampshire, in Sheets 11 and 15; the gravel and sand of that county being, so far as I know, all of that unfossiliferous character which marks the gravel and sand of the great submergence and the recovery therefrom (*b'*, *c*, *e*, and *f*) everywhere except in the north-west of England and the Severn valley; but as South Hampshire must have participated in the same redepression as Sussex, we must infer that the sands deposited there by the sea in question up to the level which this reached at Avisford have either been removed, or else are undistinguishable from the gravels of the original submergence and the recovery therefrom (*e* and *f*), which in level correspond to the upper limit of this redepression, in the same way that much of the *Cyrena*-formation in the Thames valley is so mixed up with the gravel, *f*, there, as (where unfossiliferous) to be undistinguishable from it; the gravels of the great submergence, which thus in Hants range almost continuously from the level of 150 up to 419 feet, being, curiously enough, absent, so far as I know, in Sussex. There appear also to be no means of ascertaining whether any of the sand and gravel with marine shells in the Severn valley represents the stage of redepression now under consideration; but as these shells comprise, according to Mr. Maw *, *Astarte borealis* and *Tellina lata* (*calcarea*), Arctic and glacial species, which, though present in the gravel of this stage in Cambridgeshire, have not been detected among the shells from the Sussex sands or from the Selsea bed, the probability is rather against such being the case.

The resubmergence to which the *Cyrena*-formation as thus traced was due, does not in its increment follow altogether the direction of that of the great submergence; for, while that increased northwestward and southwestward from East Norfolk and North Suffolk, this appears to have increased westward and northward from Kent; and while the former accompanied the major glaciation, the latter seems to have preceded the minor. Except for this, since the greatest increment in both cases was in the direction of the mountain-districts, and the small extent of the minor submergence corresponds to the small amount of the land-ice which the morainic formation of the minor glaciation indicates, the view that the submergences were due to the pressure of the land-ice which accumulated on the mountain-districts would be quite borne out, though the final depression of England indicated by the submerged land-surfaces mentioned in the sequel can have been due to no such cause.

The position of the *Cyrena*-formation in the Thames valley below London, when examined in connexion both with the gravel *f* and the gravel *g*, shows that this part of the valley and the corresponding part of the Lea valley has been subjected to much dis-

* Quart. Journ. Geol. Soc. vol. xx. p. 140.

turbance since that formation, by which, it seems to me, the denudation was induced which has removed the greater part of it there: and in order to enable this to be seen, I have given the many lines of section across this part of the valley which are contained in Plate XXVI. A consideration of all the features thus disclosed will, I think, show also that this disturbance with its resulting denudation was renewed after the accumulation of the gravel *g*. Such disturbance with denudation of the bottom seems to be the usual accompaniment of any general movement of upheaval; for in the case of that great one which took place during the major glaciation, it gave rise to the rectilinear upturn of the Hogsback, which placed the gravel *b'* in the position shown in fig. II., and to that of the Isles of Wight and Purbeck, which placed the same gravel in the position shown in fig. IV.*; while in the case of that minor one which took place during the *Cyrena*-formation, and the minor glaciation which followed this, it gave rise to the disturbances I am about to trace.

In Sheet 1 (see Map 3) there is on the south side of the Thames, between Greenwich and Erith, neither gravel nor brickearth *of any kind* above the marsh alluvium, except the isolated patch of the *Cyrena*-brickearth in Wickham Lane shown in fig. XXXIII., and the trace of this on the chalk in fig. XXXIV.; while both to the east and west of those places gravel rises to elevations exceeding 100 feet (see figs. XXXVII. and XXXVIII., and figs. XXI. and XXII.). Between Greenwich and Erith, where the beds *f*, ϕ, and *g* are thus absent above the marsh, the Lower Tertiaries below it are known to be faulted†; and this is probably the case also between Crossness and Wickham Lane in fig. XXXIII. The connexion of the gravel with these faults is concealed by the peat and marsh clay, except at Charlton; and there the disturbance connected with these faults brings up the chalk bare of gravel, not only on the south side of the river, but in the south side of its bed, though the northern half of the river-bed here, like the northern shore, is gravel-covered. Over the whole northern side of the valley corresponding to this deficient southern part, the gravels *g* and *f* (and so much of the *Cyrena*-formation, ϕ, as may be left there) spread in a continuous sheet up to the elevation of 100 feet and more (see figs. XXXIII. and XXXVIII.), and no terrace, save such as *g* and ϕ make in fig. XXXVIII., can be detected. East of this, in the part crossed by the lines of figs. VI. (see plate to first part of this memoir), XXI., and XXII., ϕ lies in a well-defined terrace below *f*, with *g* in a terrace below and up to ϕ; but more frequently ϕ is absent, and its place occupied by *g* lying (up to the level of from 25 to 30 feet above O. D., which it reaches here) in a terrace below *f*, as shown at the

* Also to that continuation of the Wight and Purbeck upturn which is shown in Prof. Prestwich's Weymouth section (Quart. Journ. Geol. Soc. vol. xxxi.), where the gravel on the Tertiary over the chalk is shown cut off at this upturn, as it is in my figs. II. to V.

† De la Condamine, in Quart. Journ. Geol. Soc. vol. vi. p. 441, and vol. viii. p. 193.

eastern end of fig. XXI. and in fig. XXIX. The valley of the Mardyke, however, both where it cuts sharply through the gravel *f* as well as where it spreads out to form the flat ground below the gravel escarpment crossed by fig. XXIX., is destitute of gravel, sand, and brickearth, though it is below the level reached by *g*, and all this gravel escarpment drains to it.

From Fobbing eastward, as far as Southend, a space of ten miles on the north side of the river is entirely destitute of *f*, ϕ, and *g*, alike down to the river-bed, neither brickearth nor gravel, save the small patch of *c* at Hadleigh Common, in fig. XXX., occurring there; and this denuded space is continued north over the water-parting between the Thames and Crouch, the valley of which last-mentioned river, like that of the Mardyke, is destitute of gravel, though the small patch of gravel *f*, shown in fig. VI., at Dunton Waylet, on the parting between the Mardyke and Crouch drainage, shows that both these valleys have been excavated out of a wide-spread continuation of the sheet of *f*, of which the scarped portion is only the remnant. See figs. VI., XXX., and XXXI.

Over the area corresponding to this on the south side of the Thames, from Swanscomb to the water-parting between the Thames and Medway, in Sheet 1, which is formed by the range of London-Clay hills on which High Halstow (in figs. XXXI. and XXXII.) stands, there is a similar absence; a patch of ϕ at Gravesend, a trace of it at Higham Station, and a patch of gravel at the Marsh-edge, one mile west of Higham, being all that I could find in this part. The other side of this parting, which slopes from High Halstow to the Medway, is, on the contrary, gravel-covered over its lower and medium elevations, as is the rest of the western side of the Medway valley in Sheet 1; and this gravel-covered slope is continued across the Thames-mouth and along the east side of Essex to the Blackwater estuary, where it terminates in a point which bounds the denuded space which I have described as stretching from that estuary across Sheet 1. The gravel slope of East Essex, thus continuing the Medway-gravel slope, is crossed by fig. XLI., which traverses also the *un*denuded north and the denuded south sides of the Blackwater estuary valley, and should in that connexion be compared with fig. XL., which, crossing that valley to the west of the denuded space, shows both sides of it *completely sheeted with gravel from b' at 366 feet at Danbury nearly to the sea-level.* It seems obvious to me that all this denuded space must have been selectively subjected to disturbance, while covered with water of some kind that, in consequence of such disturbance, denuded it.

The Lea valley, also, from Chingford to Broxbourne, *i. e.* throughout nearly all the northern half of Sheet 1, is, on the east side, destitute of gravel or brickearth down to the Marsh-edge; while on the west side it is sheeted with gravel from the Marsh up to elevations which, northwards, exceed 150 feet (see Map 3 and fig. XXXIX.). A comparison of these features of denudation with those shown in Mr. Codrington's map of the South-Hants gravel-area indicates to my mind that a similar selective denudation has taken place there.

And of those geologists who attribute such features to atmospheric agency, I would ask, Why does that agency, which is common to the whole surface, operate in this selective way, removing gravel and brickearth from great spaces and leaving it intact in others, the formation on which these rest in both parts being the same? Not only has the denuding agency so operated, but it has, along with the removed gravel and brickearth, carried off considerable thicknesses of the formation on which these rested, though of the diverse character which clay, marl, sand, and chalk present to the denuding action.

Thus, it appears to me, both the *Cyrena*-formation and the gravel *g* have, within the eastern part of the Thames valley, been subjected to much disturbance. This, when that valley was covered by water up to the elevations at which remnants of ϕ 4 occur (which is near 100 feet at Grays, and quite that by Dartford Heath, and proportionately higher west of London and up the Lea valley), began with the rise from the depression which I have traced in this stage, and throwing this water against the east side of the Lea valley, washed away from there the gravel *f*, on which the *Cyrena*-formation had rested, as well as that formation also; and acting upon the wider space described in the east of Sheet 1*, washed this away from that part also. A similar disturbance, repeated after the pause in the rise had allowed the gravel *g* to accumulate, washed away that gravel also from the same areas, at least above the present Marsh-level; and looking at the wide spaces from which the sand and gravel within the limit up to which the depression of the *Cyrena*-formation must, in South Hampshire, have extended, to correspond with its position in Sussex, has, according to Mr. Codrington's map and sections, been removed, much of this disturbance and denudation must have prevailed in that area also.

The formations which were accumulated during the rise from the redepression just traced, and during a stationary period due to a pause in such rise, I proceed to trace in Stage VII.

Stage VII. *The Minor Glaciation, or Reindeer-Period.*

In the Journal of the Society for 1868, p. 846, Mr. Rome and I brought to the notice of geologists that in East Lincolnshire and Yorkshire there occurred a clay differing in character from the general mass of the glacial clay of that region, and which latter the Holderness-Cliff section showed it to wrap like a cloth. For this, as the word "Upper Boulder-clay" was misleading, from its having been applied to the Chalky Clay to distinguish that from an anterior bed, we proposed the name of the "Hessle Clay," from its best-known section occurring at Hessle, four miles west of Hull. From the subangular condition of the chalk débris in this clay, so different from the very rolled character of that débris in the Basement Clay (B of

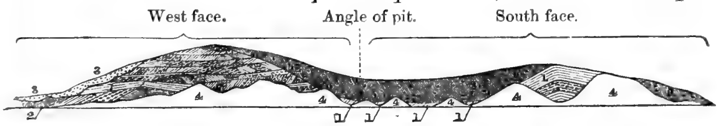
* The water seems also to have been thrown against the eastern side of this space both north and south of the Thames, see figs. XXX. and XXXI. It is impossible to say to what extent sand representing part of the *Cyrena*-formation may have escaped this denudation, and be mixed up with the gravel *f* shown in the lines of section which I have given across the Thames and Lea valleys.

figs. XLVI. to XLIX.), wherein it is incomparably more abundant, and from that in the Purple Clay (D of the same figures), it is clear that the Hessle Clay had in some way a different origin from either of these, from which also it is usually separated by the *Cyrena*-formation, except where it rises to elevations above those to which the submergence in which this formation originated reached, or where it has cut out that formation (see Γ of figs. XLIII. to L.).

Wrapping the clays of the major glaciation thus in Holderness, the Hessle Clay also extends down the coast-region of Lincolnshire, covering the low ground east of the Wold nearly to the Wash *, being there, as borings have disclosed, underlain by gravel, which seems referable to the *Cyrena*-formation; but it makes no appearance either on the Wold or in the country west of the Wold in that county, whether at high or low elevations. To the north of the Humber it spreads over South and Central Holderness, ceasing in northern Holderness at the point where its place is taken by the considerable accumulation of sand with some included gravel, shown in fig. L. by the letters Γ γ, and which at its southern extremity seems to pass over the edge of this clay.

The deep section of sand and gravel wherein the *Cyrena* abounds, in association with marine Mollusca, at Kelsea Hill in Holderness, was in 1867 to be seen overlain by the full thickness of this Clay, possessing exactly the characters of subangular chalk and small rounded boulders and stones which it has on the coast-section, as in the subjoined cut, taken from the paper of Mr. Rome and myself above mentioned.

Cut iv.—*Kelsea-Hill Ballast-pit in April* 1867, *Point* A O *on Map* 5.



1. The gravel with *Cyrena fluminalis* in association with marine shells (Φ of the plate). 2. The Hessle Clay. 3. Gravel, either rainwash, or *h* of fig. LVI. 4. Talus.

N.B. The gravel with *Cyrena* was found by borings to be underlain by a great thickness of the Purple (and probably also of the Basement) Clay.

Though from my first knowledge of this clay I have referred it to a minor glaciation posterior to the great submergence and glaciation of England, and connected it and the gravel it covers with the beds exposed in the *Cyrena*-brickearth sections in the Thames valley, yet I have attributed its formation to marine agency and coast-ice, and opposed the view of Mr. James Geikie that it was a product of land-ice and terrestrially accumulated. And in that view I have been supported by Mr. Jukes-Browne, who has traced this clay a few miles further south than Mr. Rome and I did. I

* A patch of sandy clay on the gravel of Stage VI. at March may belong to the Hessle Clay, as this clay becomes more sandy in that direction; and if so, would show that this clay reached a little south of the Wash.

have, however, come to see that Mr. Geikie was right in his contention, being led to this partly by the absence of any trace of molluscan remains in this clay, but more particularly by a consideration of the areas over which it occurs. As regards the first point, viz. the absence of shells, this formation is like the Chalky Clay; and it is, I think, clear that in the case of both clays this is due to the fact of the moraine which the clay represents not having been extruded subaqueously; while the opposite character, which marks the synchronous Upper Clay of the north-west as well as the Lower Clay of that region, is due to both these having been so extruded, owing to the abrupt way in which the submerged area was in that part of England bounded by the mountain-district. As regards the second point, the distribution of the Hessle Clay, I was perplexed by finding no trace of this north of Bridlington, from which place to Scarborough I closely examined the cliff; for it was clear to me that the Upper Clay of Filey, which at the "Brigg" (in Sheet 95) passes over the edge of the clay occupying the preglacial valley of Pickering, was not it, but the Purple Clay (D of figs. XLVI. to L.), with which it was continuous. Nor could Mr. Rome recognize it from Scarborough northwards until the coast-section begins to intersect the mouth of the preglacial valley of the Tees at Saltburn (on the western edge of Sheet 104). There, however, he found it; and together from that place we took up the examination again, finding the clay continuously westwards through the Tees valley up to Yarm (in the south of Sheet 103), and reaching to elevations of near 400 feet, where, and down to elevations of about 100, it rested on the clay of the major glaciation; but below this elevation it rested on the sand and gravel which I have referred to the *Cyrena*-formation.

When I came analytically to examine all the phenomena connected with the subject of this memoir, I perceived that the presence of this clay up to such elevations against the northern flank of the East Moorlands, which forms one side of the Tees valley, and its absence at all elevations on the eastern flank* was inconsistent with a marine origin, and that the clay must be the moraine of ice issuing through this valley, and through that of the Humber, seeking the sea in its present position.

The different character of its débris then became explicable; for while from the height to which the ice must have risen within the Tees valley it collected *there* the same material in its moraine as did that of the Purple Clay (except the Shap blocks), though the boulders are fewer and generally of less size, the height to which it rose in the lower part of the Vale of York was so small that, following the centre of the valley, it passed *there* only over the *Cyrena*-formation. From this it collected much of its débris, and it was only after it

* I have (*ante*, p. 685) explained that the Upper and Lower Clays of the eastern valleys between Scarborough and the Tees seem to me to be like those of Filey cliff; but I have not, as I have in the case of Filey, personal observation on which to rely in stating that the Hessle Clay is thus absent further north than Scarborough.

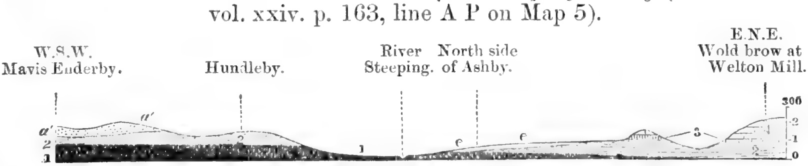
arrived at the Humber-gorge, that it collected some subangular chalk. Then spreading out over the low ground of Holderness and that which skirts the seaboard of the Lincolnshire Wold, it enveloped those parts with a coat of moraine everywhere of small thickness, but thickest in the hollows, as it appears in the foregoing cut of Kelsea Hill, where the small boulders in it, other than the subangular chalk, appear for the most part to be derived from the coarse gravel-beds in the *Cyrena*-formation which it overlies. Thus this clay in Holderness and East Lincolnshire has scarcely any of that small angular rock débris with which the Purple Clay it often rests upon is crammed. What little it may have of this (and I never observed any) may well have been collected from the Purple Clay over which it passed. On the other hand, while chalk débris gradually disappears from the uppermost part of the Purple Clay where this is thickest, as in fig. XLVI., the Hessle Clay thus wrapping it has much chalk, but of the more subangular shape which distinguishes it from the rolled chalk of the Purple and Basement Clays.

The Kelsea-Hill section given in Cut iv. p. 713, and figures XLVI. and XLVII. of the Plate, show the way in which this ice, thickening in depressions, has cut into and cut out the *Cyrena*-formation Φ, and laid its moraine (Γ) in the parts thus cut out, as well as over Φ. The woodcut also shows the ridge-like arrangement of the beds described by Mr. Dakyns in the case of the same sand and gravel, where it is overlain by this Clay near York, as "dipping away from the crown of the arch" (p. 386 of vol. xxviii. of the Journal). This seems to have been caused by the lateral pressure of the land-ice in the hollows of the gravel.

There is on the west side of the Humber-gorge a low tract occupied by alluvial accumulations of recent origin, which seems to have been a hollow excavated by this ice thickening there in consequence of the constriction caused by that gorge.

Another important feature in this clay is the way in which, towards its southern extremity, it passes the mouth of the Steeping valley, and, as it were, peeps into it, making only a slight deflection so as to occur on one side of it only, and just at the mouth. Had the clay been an aqueous accumulation, it should stretch up this valley, just as the marine brickclay of the *Cyrena*-formation extends up the valley of the Nar. The accompanying cut, taken from the paper of

Cut v.—*Section across the Mouth of the Steeping Valley* (from vol. xxiv. p. 163, line A P on Map 5).



1. Jurassic. 2. Neocomian. 3. The Red Chalk. 4. The Chalk.
a. The Chalky Clay, consisting here of reconstructed Chalk similar to that of the masses buried in the Contorted Drift of North Norfolk. *e*. The Hessle Clay.

Mr. Rome and myself, shows the mode of its occurrence in the mouth of the Steeping valley, a confirmation of which will be found in Mr. Jukes-Browne's paper on the Hessle Clay in vol. xxxv. of the Journal, p. 397. The distribution of the clay is shown on Map 5, wherein the place of this cut is indicated by the letters A P.

The valley of the Steeping, in which the Hessle Clay thus lies, is cut out of the Chalky Clay that originally lay up the Wold, but was washed out, it seems to me, by the ice-water during the retreat of the ice of the major glaciation, as described in the first part of this memoir (p. 505).

The thick outspread of sand with gravel which intervenes between Bridlington and the northern edge of this wrapping of Hessle Clay in Holderness ($\Gamma\gamma$ of fig. L.) may, I think, have resulted from the effluent water of this edge of the ice of the minor glaciation in the same way that the gravel and sand of West Norfolk described in Stage IV. resulted from that of the edge there of the ice of the major glaciation; and small pocket-like patches of gravel which cut through the continuous cover of Hessle Clay along the Holderness Cliff, and are marked by the letters $\Gamma\gamma$ in figs. XLVII. and XLIX., appear to me to have had their origin also from the water of this ice.

I have already mentioned that the upper clay of Northumberland, Cheshire, Lancashire, and Cumberland is, in my view, the moraine of this minor glaciation; and all of it resembles the Hessle Clay in the small thickness of the formation compared with the clay of the major glaciation, in the paucity and smaller size of the boulders, and even in the red colour of the clay, though to what cause such a similarity of colour can be due it is hard to suggest. This identity is even further shown by the Upper Clay in Lancashire being frequently penetrated by vertical partings of cinereous colour, a character which is constant with Hessle Clay in Holderness, and which partings I could not perceive ever to occur in the Purple Clay where that forms the surface. The partings are of course due to atmospheric agency.

The difference in conditions between the east and west sides of England during this minor glaciation is only the supplement to the important feature which throughout this memoir I have dwelt upon as the key to the whole question of the Newer Pliocene period, viz. the westerly increment of depression; and thus it is that while we find no shells in the Hessle Clay, nor any bed posterior to it on the eastern side which furnishes indication of any part of this side having at the close of that clay been below the sea-level *, we find both of these features in the case of the Upper Clay of the north-west, as described in the sequel. It appears to me that the land-ice in which this morainic clay originated did not extend so as to reach the sea until the greater part of the depression in which the *Cyrena-*

* I found the Hessle Clay exposed in full section resting on the sand, Φ, 35 feet below spring-tide high-water mark in the Hull dock, when the excavations were in progress; and there was no more indication afforded by it in that position of a marine origin than there is at its highest elevations. This shows, I think, that the sea-level was at this time, in Holderness, 25 feet at least below the present.

formation originated had been recovered—at any rate in the eastern and southern parts of England—when a pause took place, and a stationary interval occurred in which the buried cliffs of the south coast were formed, and the gravel *g* accumulated. This brought the sea-level in the east to about the point at which it stood when the subsidence in which the *Cyrena*-formation originated began; and this, judging from the evidences of transit from freshwater to marine conditions at Clacton in Essex, and Overton in the Fen-country, and the other phenomena examined in connexion with that formation, was in the east somewhat below what is now the sea-level there; so that the rivers of Norfolk, Suffolk, Essex, and North Kent had further to travel to reach the sea than now, and their waters swollen by the melting snow in summer rose to that higher level than now which is marked by the upper limit of the gravel *g* in the Thames valley. At the same time the ice-streams from the Pennine which passed through the vales of York and Tees reached the sea at the same proportionately greater distance, but in the same direction as now; that one which passed through the vale of Tees continuing eastwards, instead of turning south along the east side of Yorkshire, as it did during the major glaciation, to form the Purple Clay; and that one which flowed through the vale of York passing out by the Humber, as it had, though in far greater volume, done, when at the commencement of the major glaciation it, from the inclination having been eastward, formed the Basement Clay of Holderness, instead of flowing southwards along the west of the Lincolnshire Wold, so as to overspread the eastern and east midland counties of England, as it did in forming the chalky clay, when, from the southerly and westerly inclination, the sea covered the southern, central, and western counties.

In the north-west, when this minor glaciation began, the plain of Cheshire and West Lancashire was still submerged, though to what height seems uncertain; and there the moraine from that side of the Pennine entered it by submarine extrusion, and the ice-floes from the shore carrying away molluscan remains, some of which contain mud full of Entomostraca and Foraminifera, dropped them as it floated over these places of submarine extrusion, so that they became incorporated in the moraine. The small thickness of the moraine of the minor glaciation, and the paucity and small size of the boulders in it, when coupled with the indication which the distribution of the Hessle portion of it affords that the ice-stream from which that portion originated was confined to the central parts of the vale of York, as well as the absence of Shap erratics from that portion which occupies the vale of Tees, conspire to show that the volume of the land-ice during the minor glaciation was small in comparison with that during the major.

It now remains to examine what evidences this minor glaciation has left over the part of England which was beyond the limit to which the moraine of the land-ice extended; all of which, save to such extent as the north-west continued submerged, had now become land.

Pursuing what has been already said as to the extent to which the depression in which the *Cyrena*-formation originated had been recovered, and the pause in the rise took place which was thus coincident with the extension of the land-ice to the sea in the way just described, or, in other words, with the culmination of this minor glaciation, we find the buried cliffs of the south fall into their places at this point. They all have marine shingle at their base; and in most of this shingle shells occur, all of living British species, save a doubtful *Rissoa**. Over this shingle, in the cases of Brighton and Portland, angular and other boulders of chalk and stone have been piled by the pressure of the ice-floes on the shore during the minor glaciation, with which seams of loam containing land-shells are intermingled; and as the rise was renewed and the cliffs passed out of reach of these floes, they and these boulders and loam became buried under the peculiar terrestrial formation due to the atmospheric agencies of an arctic climate which I am about to describe, and which in my figures is shown, under the letter γ, to correspond with the formations of synchronous but dissimilar origin shown under the letters Γ, G, G', and *g*.

In arctic countries, like Siberia, the soil is permanently frozen to a considerable depth, only the upper two or three feet of it thawing during summer. In this thawing part vegetation not only grows, but flourishes. It is obvious, however, that the part below remaining frozen is impermeable by water, so that, as this can have no escape vertically, it must convert the thawed layer into sludge; the tendency of which is to slide horizontally from higher to lower ground, thus accumulating more and more in depressions, and exposing more and more of the surface from which it slid to the operation of this agency, and so keeping up the supply. The frost and thaw thus acting upon limestone-rock, which is partially porous, has split it up into angular fragments, which became dispersed in the resulting sludge; and the same thing acting upon the flints in the chalk split them into splinters, which have become dispersed in like manner†. In the case of the major glaciation those islands of chalk shown in Sheets 46, 13, and 34 of Map 4, as not reached by the chalky clay, are covered with the atmospheric formation thus resulting during that period, which is the clay with flints; and in the case of the pebble-beds of South Essex, shown in fig. VI. by the number VIII., and which became land at an early part of the emergence, this agency, while the land-ice filled the valleys shown in

* Neither of the two peculiarly Lusitanian species of the Selsea bed occur among them; and the whole assemblage is the reverse in character of the Mollusca of that bed; for while the rest of the species there, other than these two Lusitanian, constitute an assemblage characteristic of our present south coast, Mr. Jeffreys observes (Journal, vol. xxxi. p. 52) that the shells collected by Mr. Prestwich from the beach at the foot of the buried cliff at Portland "are rather northern than southern" in their type.

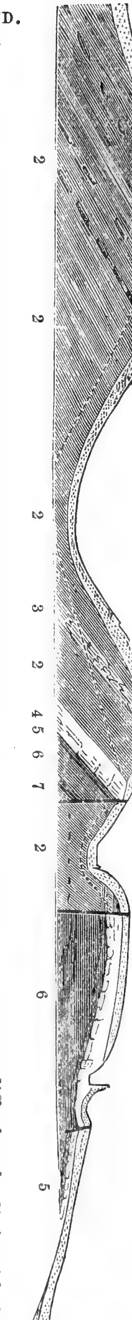
† This slide of the soil-cap takes place now in Patagonia from the wetness of the climate alone, according to Dr. Coppinger, in vol. xxxvii. of the Journal, p. 348. *A fortiori*, would this go on under the conditions described in the text; while wetness of climate would not rupture the limestone into fragments, or the flints into splinters, such as abound in the formation I am describing.

that figure as occupied by the chalky clay, but left these pebble-capped eminences (Stock and Billericay in the figure, and Langdon, Warley, Havering, South Weald, Frierning, and other hills of South Essex) exposed to the atmosphere, has covered them with a bed of clay-gravel four or five feet thick, in which the pebbles (which in the original beds, No. VIII., rest horizontally on their shorter axes) are for the most part set up vertically on their longer axes. An accurate representation of a section at South Weald showing this is in the Geol. Survey Memoirs, vol. iv. p. 324.

By permission of the Council, I give here, from a paper by Mr. R. N. Mantell in the sixth volume of the Journal, a representation of a cutting at Trowbridge, wherein the Jurassic strata are enveloped by this formation, in which Mr. Mantell says the bones of mammalia occur. The site of this, which is in the N.W. of Sheet 14, was sea during the formation of the Chalky Clay, and is so represented in the continuation of Map 2. The atmospheric formation there can thus be that of the minor glaciation only.

The atmospheric formation thus arising during the minor glaciation is, it seems to me, also represented by the amorphous cave-earth, which, sliding over the surface, has penetrated the fissures of the limestone in which the caves occur*, and so entered the caves, carrying with it the bones not only of all animals which, dying on the land, were preserved

Cut vi.—*Section exposed by the Trowbridge Railway-cutting* (from paper by R. N. Mantell in vol. vi. of the Journal, p. 312



1. Drift, described in Mr. Mantell's paper as from 2 to 8 feet thick, covering the surface everywhere, and sometimes difficult to be distinguished from the decomposed Oxford clay, being of the same yellow colour, and containing a few elephant's teeth with shells from the Oxford clay and pebbles of Cornbrash. (γ of my figures.)
2 to 7. Jurassic strata consisting of the Oxford clay, Kelloway rock, Cornbrash, and forest marble.
8. Gravel.

* The Victoria Cave, near Settle, being within the area of the land-ice of this glaciation, is not filled with this amorphous earth, but with finely stratified clay due to aqueous deposition, possibly by water from beneath the land-ice.

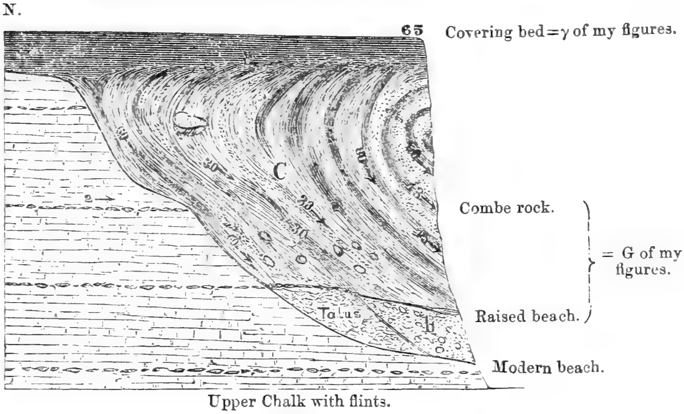
by the antiseptic character of an arctic climate, but also, I suspect, the bones of animals which, having left their remains in the superficial formations of the last preceding period (and possibly even of those which, dying as the arctic climate was coming on, were preserved in mere soil by this climate), became mixed up in this earth with those of animals, such as the Reindeer and Mammoth, which inhabited the country during this glaciation.

The cave-earth, as is well known, is invariably sealed up with an overlying layer of stalagmite, and in some instances it is also underlain by this. It is well known that stalagmite is the deposit of carbonate of lime formed by the percolation of rain-water through limestone-rock; and it is obvious that when the soil is perennially frozen in the way described, so that no vertical escape of the rain- or snow-water can take place, no stalagmite can form though the fissures give access to the sliding mud which becomes cave-earth. Hence the absence of stalagmite *during* the formation of the cave-earth; that which underlies it having been the result of infiltration during the mild climate which preceded and partly accompanied the *Cyrena*-formation in such caves as were not at that time submerged; and that which overlies it having been the result of infiltration since the minor glaciation passed away. In caves that were in existence before the great glaciation, we might expect three layers of stalagmite—the lower of preglacial age; the middle of the age preceding the *Cyrena*-formation; and the upper of the time since the minor glaciation passed away; and such appear to occur in caverns near Liége beyond the limit of the Newer Pliocene submergence.

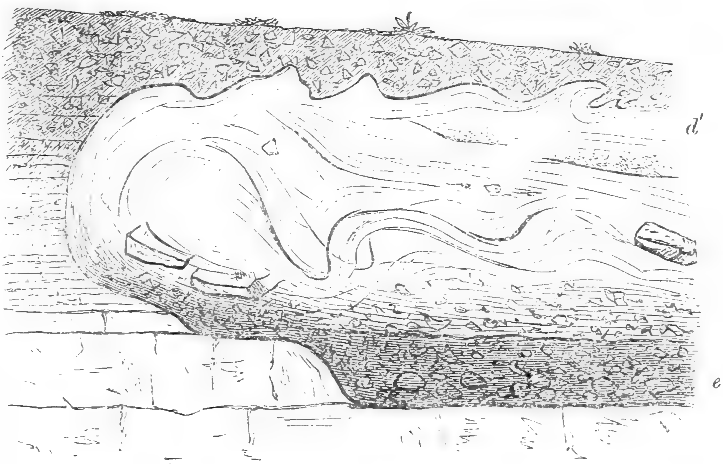
This is the formation also under which the cliffs of Sangatte, Brighton, Isle of Wight Foreland, Portland, and Sili Bay are buried, the splinters of flint and limestone produced by the splitting-up action of the intense frost upon the flints and stone, to which I have referred, being distributed through the burying material in all the cases. In Mr. Codrington's representation of the buried cliff of the Isle of Wight Foreland, which I have copied in fig. LV., the accumulation which I have described as resulting from the packing of the ice-floes on the beach, and which at Brighton and Portland first filled up the cavity made by the cliff-face, and presents the appearance of having been doubled back on itself, is not shown; the whole of the cliff-cavity being represented as filled with the earth with angular fragments of flint. The remains of the Elephant have occurred in the material under which the old cliff at Brighton is buried: and Mr. Mantell mentions that they also occur in the bed 1 of his section.

By permission of the authors and of the Council, I here give the cut representing the buried cliff of Brighton from Mr. A. Tylor's paper in the 25th volume, and that representing the buried cliff of Portland from Prof. Prestwich's paper in the 31st volume of the Journal, each of which shows this doubling back.

Cut vii.—*Section of the buried Cliff at Brighton* (from paper by Mr. A. Tylor in vol. xxv. of the Q. J. G. S. p. 79).



Cut viii.—*Section of the buried Cliff at Portland* (from paper by Prof. Prestwich in vol. xxxi. of the Q. J. G. S. p. 36).



d. Angular débris 4 feet. = γ of my figures.

d'. Light-coloured loam with seams of débris and angular blocks. Land and freshwater shells in places, 11 feet. *e* Raised beach with very large pebbles at base, 7 feet (24 species of Mollusca found in this by Prof. Prestwich at various points, and all British). = G of my figures.

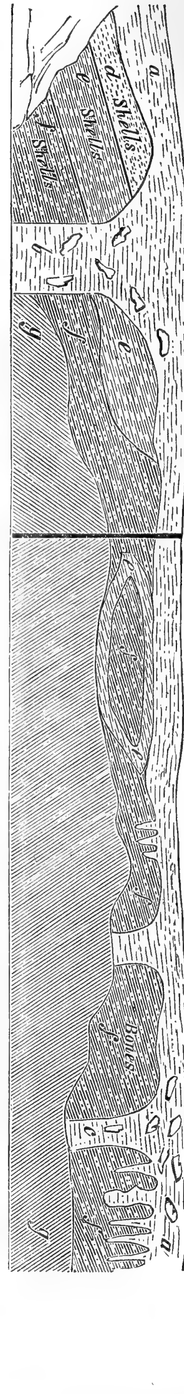
Rills of muddy water, carrying with them land-shells, pouring over the face of these cliffs during the minor glaciation, and when the ice-floes packing on the shore piled the blocks of stone and

chalk on the beach, gave rise to the irregular seams of loam with land-shells, described by Prof. Prestwich as overlying and intermingled with these blocks in the buried beaches of Sangatte and Portland; and the pressure of the floes repeated year after year probably forced this accumulation more thickly against the cliffs, so that the upper part turned over on itself; or it may have been that floes thus driven on to the shore became buried under loam before they could thaw, and so became part of the permanently frozen soil, as is the case with sheets of ancient flood-water still remaining as ice in the mudbanks of the Siberian rivers from which the Mammoth carcasses have been detached. If so, the thawing of this ice after the glaciation passed away would have let down the loam &c. accumulated over these floes and around their edges, and so possibly have given rise to the distorted appearance which the accumulation exhibits in Mr. Prestwich's cut of Portland buried cliff.

By permission of the Council, I also give here the late Mr. Trimmer's cut of the brickfield at Gaytonthorpe, in West Norfolk.

The beds *d*, *e*, and *f* of Mr. Trimmer's section are, he considered (and as I think also), a freshwater continuation, at proportionally higher level, of the Nar brickearth; and therefore, like the Avisford sand, of the age of the *Cyrena*-formation; and like that they are overlain and penetrated by the atmospheric formation of

Cut ix.—*Section at Gaytonthorpe* (*N.E. of Sheet* 65 *of Map* 5) (from paper by Mr. J. Trimmer in vol. vii. of the Journal, p. 28). Vertical and horizontal scale 20 feet to 1 inch.



a. Warp of the drift, sandy loam containing unabraded flints, some of them of large size as at *b* and *c* = γ of my figures.
d. White calcareous sand. } Freshwater beds
e. Grey and yellow silt. } containing *Cyclas*,
f. Grey clay. } *Planorbis*, & *Unio*.
g. Drift resembling the most chalky varieties of the Till and containing fragments of Chalk with flints, and of Kimmeridge Clay and other Oolitic rocks.

the minor glaciation (*a* of Mr. Trimmer's section, and called by him the Warp). Just as the splintered flints in the brickearth which overlies the Avisford sand, in that which overlies the buried cliff at the Isle of Wight Foreland, shown in fig. LV., and in the corresponding material which overlies the buried cliffs of Sangatte and Brighton, cannot have been derived from atmospheric action upon the formation on which they rest, but must have travelled for some distance over the surface, so have the flints which Mr. Trimmer thus represents as occurring in this overlying "warp" * come either from the chalk surface which occurs at some distance from the section, or from the Till which, though shown in the section as underlying the freshwater beds *d*, *e*, and *f*, forms the surface at some distance, and not from any action upon these subjacent beds *d*, *e*, and *f*, which do not contain such flints.

In his diagram section of the beds in the Selsea peninsula, which I have given at p. 708, Mr. Godwin-Austen shows the shingle and gravel overlying the clay-gravel with large hypersthene-rock blocks, as overlain by this brickearth with splinters of flint, and this, he says, overlies all the gravel and other beds of the Sussex levels. In this shingle, clay-gravel, and overlying brickearth we find the exact parallel of the buried cliffs, thus.

The shingle at the Brighton cliff is, according to Mr. Tylor, 10 feet above high-water mark, while that in Mr. Codrington's figure of the Isle of Wight Foreland (fig. LV.) has its upper limit at about 60 and its base about 20 feet above O. D. Selsea is nearer to the latter than to the former; and if we take the upper limit of the shingle as representing high-water mark of spring tides, we may infer that at the date of these beaches the mean level of the sea over the Selsea peninsula was about 40 feet above the present. Now this agrees with the position of the gravel with great erratics, the elevation of which, as shown in fig. XLII. †, is uniform at from 15 to 20 feet above O. D., which would give a mean depth of from 25 to 30 feet of water over it at the time of this gravel.

It seems to me obvious that just as this part of the coast is a flat at the present time without cliffs, and extends from opposite the eastern end of the Isle of Wight (with its higher ground, and consequent cliffs) to Brighton, where the same cliff begins again, so was it also when the buried cliffs were washed by the sea during the stage under consideration, and the shingle accumulated at their feet; the mean sea-level at Selsea just mentioned allowing the floes to

* Mr. Trimmer referred this Warp to the action of the sea during the last geological period, contrary to my view of its origin. Mr. O. Fisher has called it "Trail," and referred it to land-ice agency during a later glaciation than the main one.

† I have constructed this figure from Mr. Codrington's gravel map (pl. xxxvi. of vol. xxvi. of the Journal), and, as to the older Tertiaries on which these gravels rest, from the Geological Survey map. It shows the comparative levels which this gravel of the minor glaciation and that of the major respectively occupy, though the greatest elevation of the latter in the section (419 feet) is 250 feet below the level to which the submergence attained in this part during the major glaciation.

ground at low water. Here the ice-floes, bringing the blocks of hypersthene-rock from the southward, grounding on the shallows where the clay-gravel (which Mr. Godwin-Austen says contains *Littorinæ* and fragments of *Mytili*) was accumulated, left these on, or in, that gravel, at the same that the floes packed against the cliffs to the east and west of this flat area. By the rise which caused the sea to recede from these cliffs, the sea on the Selsea coast became too shallow for the floes to pass, and the clay-gravel gave place to a more littoral gravel with sand and shingle, with shells (*c* of the diagram at page 708), the tidal movement, which accompanied this, wearing away the surface of the clay-gravel. Then, by the continuance of the rise, this became land; and thereupon it was overspread by the same atmospheric formation with flint-splinters that buries the cliffs and overlies the Avisford sands, viz. *b* of the diagram. In South Lincolnshire I have met with this formation, γ, capping in a thickness of three or four feet the Jurassic limestone of that county, and containing, like the intrusive cave-earth, angular fragments of the limestone, just as it does splinters of flint where it occurs in the vicinity of Chalk; and there it is overlain by a thin bed of limestone fragments worn flat (see bed $\gamma\eta$ of fig. LIV.). All this part of England during the major glaciation was buried beneath the land-ice of the Chalky Clay (this Clay, though not covering the limestone in the figure, being within two miles of it), which protected the surface from atmospheric action, when the islands not thus protected (not merely those shown in Map 4, but those formed by the higher eminences of the Chalk Downs of Kent, Wiltshire, &c.), by being subjected to it, received the atmospheric formation of clay with flints which covers them. The medium and lower elevations of the South and West of England were at the same time protected from this action by being submerged, so that it is only to the frost of the minor glaciation that any of the instances which I have given of this formation under the letter γ can apply.

In his sections (at pages 216 and 218 of the 15th volume of the Journal), Prof. Prestwich shows the Avisford and Waterbeach sand and shingle, which I have referred to the culmination of the *Cyrena*-formation depression, overlain and deeply "ravined" by the loam with angular flint fragments, γ, which I consider to have thus originated by slide from the chalk of the contiguous South Downs; and he shows this sand and shingle cut through by a small valley, the bottom of which is occupied by a bed of gravel. This gravel appears to me to be *g* of this memoir, and to be a valley-bed coeval with this loam, in the same way that γ in fig. XXVI. is the fluviatile equivalent of *g* in fig. XXV. This Avisford sand and shingle, being at a considerably higher elevation than the foot of the buried cliffs of Brighton and the Isle of Wight, had become land before these cliffs had come into existence; and the small valley thus cut through it, and occupied by *g*, was excavated in the same interval in which the break-up and denudation of the *Cyrena*-formation in the Thames valley, and the constitution of the river-channel in

which accumulated *g* of the Thames valley, took place, which I have described in Stage VI. The *Cyrena*-gravel of the Somme valley is overlain with similar loam; and in the 'Geological Magazine' for August and September 1882, I have suggested that the Loess which covers so much of the Europæo-Asiatic and North-American continents, through latitudes where, during the glaciations, the soil must have been permanently frozen, but where there was no land-ice, originated from the action here described by me. I have also there endeavoured to show, in more detail than my space here allows, the precise way in which, by the continuous rupturing of the flints of the upper chalk by the intense cold on the unprotected surface, and by the lateral escape through this thawing and moving surface-layer of the water with which it was saturated, after it had taken up the chalk by solution, the loam of Picardy with angular flint fragments arose—those thicker accumulations of it which occupy the parts of the plateaux above the level to which the submergence of the major glaciation reached having originated during both the major and minor glaciations; while that which occurs on the valley-sides and overspreads the *Cyrena*-gravel of the Somme, and is of much less thickness, originated during the minor only; these valleys having been filled with the sea, and so exempt from this action, during the major glaciation.

Although the origin of the material with fragments and splinters thus burying the cliffs appears to me of this nature, and the position it occupies, not merely in relation to these cliffs but also in the general sequence of events, to be clear and consistent, yet Prof. Prestwich * has taken views so contrary to those at which I have arrived, that I cannot pass from the subject without some examination of them.

In describing the features connected with the buried cliffs of Portland and Sili Bay, and other localities along both the French and English coasts of the British Channel, he attributes the origin of the burying-material to a great submergence, with which he connects the destruction of Palæolithic man and of some of the great Mammalia.

In the particular case at Portland, he contends that this submergence took place after a great denudation had occurred over a line of upthrow similar to that which has taken place to the south of the gravel crowning Cæsar's Camp Hill in figs. II. and III., and Headon Hill in figs. IV. and V., in the plate accompanying the first part of this memoir; and in his sections he shows this upthrown and denuded space as overlooked by gravel formed prior to this upthrow, and crowning the chalk escarpment, just as the correspondingly upthrown and denuded space of the Weald is overlooked by the gravel of Cæsar's Camp, and that of the Isle of Wight is skirted by the gravel of Headon Hill in these figures. The line of chalk upthrow connected with this great denudation behind Portland is a part of that of the Isle of Wight, which has placed the Headon gravel in the

* See the papers of Prof. Prestwich already cited, and another in British Association Proceedings in 1880.

position it now occupies, the two areas being connected by the continuation of this line through the Isle of Purbeck. The excessive denudation which has taken place along this line of upthrow and left the gravel on the Chalk Down behind Portland in a similar position to that which it occupies on Headon and Cæsar's Camp Hills, I attribute to the selective action of the sea, beneath which the movement took place, on the strata which were shattered by it, and brought under this action by the continuous though gradual rise of the shattered sea-bottom, during Stages III. to V.; but Prof. Prestwich seems to attribute it to atmospheric agency.

To the south of this upthrown and denuded space is the high-land of Portland, on the seaward slope of which lies the old beach up to the foot of the buried cliff (*e* of cut viii.); while at the foot of the landward slope of this high-land *, and skirting the south of this denuded space, Mr. Prestwich shows a very thick talus of the burying material, or "Landwash" as he proposes to call it, identical with *d* of the cut, in which he says fragments occur of the Middle Purbeck beds which are now not to be found *in situ* on this high-land; and it is on this that he mainly founds his opinion that the material of this talus, and that corresponding to it (marked *d* in the cut), under which the cliff is buried has had a marine origin, and is the result of that submergence of 1000 feet or more, of which, in the subsequent paper read before the British Association meeting of 1880, he speaks. This "Landwash" contains, he says, land-shells in intercalated seams of loam, and mammalian remains. Prof. Prestwich thus assigns the Newer Pliocene submergence to a very much later date than I do (unless it be that he considers this great submergence to have taken place twice†, which I do not), and he refers to it as its evidence, not the gravel which in the successive stages of its emergence forms so large a part of the subject of my memoir, but an accumulation which appears to me to be exclusively of terrestrial origin. With respect to this accumulation and the burying of the cliffs under it, I have already observed that cliffs of such yielding material as chalk or marl could not escape being planed off by a submergence; and though the cliffs of Portland and Sili Bay are of more unyielding material than those of the Isle of Wight Foreland, Brighton, or Sangatte, yet if one of these was buried by submergence, so were

* From the representation which Mr. Prestwich gives of this talus, it seems to me that traces of the old shore-line represented by the cliff and shingle may not unlikely be concealed under it, though he regards the hollow it occupies as all originating since the cliff.

† In a paper read before the British Association meeting of the following year (1881), Prof. Prestwich describes the submergence of the South of England as having taken place during the formation of the pebbly sand *b* 1, which, though I do not agree in many of the details, is substantially what I had previously shown, in the first part of this memoir, in connexion with this sand and its modification in Norfolk into the Till and Contorted Drift, and its representation southwards and westwards by the gravel *b'*, as submergence proceeded. I can only therefore infer that Prof. Prestwich regards this great submergence as having been repeated, when the cliffs were buried late in the Newer Pliocene period.

the others; and therefore the objection, if applicable to some, becomes applicable to all.

The accumulation, moreover, though thick in hollows such as the cliffs, or beneath a steep slope as a talus, is not shown in Mr. Prestwich's sections at all distributed generally as a marine deposit would be; and without dwelling upon the gradual way in which any submergence, however rapid, geologically speaking, would first fill the valleys, and, after planing off all preexisting cliffs in yielding strata, rise from level to level, it seems a far less demand to make on our reason to suggest that the presence of fragments of the Middle Purbeck in this accumulation may be explained either by patches of that formation *in situ* being overlooked or concealed from view, or else by their having been altogether removed by the agency which introduced the fragments into this accumulation, than to explain the case by resort to a great submergence, which is diametrically in contradiction to all the phenomena traced in this memoir, and, as it seems to me, irreconcilable with the presence of seams of loam containing tender land-shells intercalated in this accumulation.

On the other hand, all the features displayed by the sections of the Portland and Weymouth district, by which Prof. Prestwich has, with his well-known accuracy, illustrated his account, appear to me, when properly interpreted, to be precisely in accordance with all that I have traced in this memoir.

Resuming now my examination of the evidences of the minor glaciation in the South of England, I proceed with the gravel *g*. This I have shown by a tint of more open dots in the Map 3, and it agrees in level with the position of the country at the time when, by a pause in the rise from the *Cyrena*-redepression, the buried cliffs and the clay-gravel with great blocks, shown in fig. XLII. by the letter G, came into existence. Mr. Codrington has correlated this marine gravel G with the river-gravel of lowest elevation of the Hampshire valleys, when these existed under a geographical arrangement which has been to a great degree obliterated by the cutting back of the Solent cliffs; and in this I quite agree with him; merely adding that I think it likely that this alteration may have been induced by those disturbances which I have shown in the case of the Thames valley to have been renewed after the formation of the gravel *g* there. It was during this pause in the rise therefore that the Thames valley became stationary at a point which allowed the Thames water during flood to rise to a level which seems to be everywhere between 25 and 30 feet above that of the present river. At Grays and Dartford the gravel *g*, which represents this flood-level, does not extend higher than about 30 feet above O. D. At Ilford (see figs. XXV. and XXVI.) it ceases between the levels of 30 and 40 feet above O. D.; for while it covers the *Cyrena*-formation in the Uphall field up to 30, no sign of it appears in the London-road field, which (except where the surface has been lowered by excavation for bricks) is above 40 feet elevation; and in lieu of it the *Cyrena*-brickearth (bed ϕ 2) is covered by the terrestrial formation, γ, already described as originating from the freezing and

thawing of the upper layer of the soil, and which was synchronous with the gravel *g*, but necessarily terminated at the limit reached in flood by the river-water depositing that gravel. To the west of London it forms what Col. Lane Fox * terms the middle and lower gravel-terrace, the upper level of which does not exceed 45 feet above O. D., and from which he obtained Reindeer-remains in association with those of *Hippopotamus*. There, as also at Brentford, where it has yielded freshwater shells as well as the Reindeer (but of course not *Cyrena* †), it passes up into a few feet of brickearth, which, though shown only between Brentford and Nottingdale on the Geological Survey Map (with some outlying patches elsewhere), is generally found overlying gravel up to the level of about 30 feet above the river up the Thames valley through Sheet 7. It was in this sheet of gravel that the skull of the Musk-Ox occurred at Maidenhead ‡.

The depression which accompanied the *Cyrena*-formation and the subsequent rise of the land to the point where this pause occurred, have in the Thames valley placed that part of the *Cyrena*-formation *in which the freshwater shells occur* at nearly the same level as the upper limit of the gravel *g*. At Grays and Crayford it is somewhat higher, but at Ilford and further up the Thames and its tributaries the elevation of the two is about the same; for if I am right in referring the sand and overlying brickearth of Col. Lane Fox's 80-feet terrace at Acton to beds 3 and 4 of the Grays pits, the lower or shell-bearing part of no. 3 is absent, the sand representing no. 3 being only the upper or unfossiliferous part of that bed, which there rests on the London Clay by transgression beyond the lower or shell-bearing part; the latter, together with 2 and 1, having been destroyed when the rise and disturbances took place that removed so much of the *Cyrena*-formation, and gave rise to the new channel in which *g* accumulated.

Thus over England generally there is nothing, so far as I can see, yet discovered which would place gravel yielding Reindeer-remains in any earlier stage of the Newer Pliocene period than that now under consideration; while the preponderating presence of these remains in all cave-earths is an important element of identity between the various formations, marine, terrestrial, fluviatile, and morainic, that I have attributed to the minor glaciation, when a climate similar in all respects, apparently, to that under which this deer mainly exists at the present day prevailed in western Europe. Negative evidence, we all know, is a very unsafe reliance; but up to the present time it may be justly asserted that no remains of this animal have occurred in any formation in England which can be assigned without doubt to an earlier stage than that of this minor glaciation §. Whether the Reindeer entered western Europe while

* 'Journal,' vol. xxviii. p. 449. † Morris, in 'Journal,' vol. vi. p. 203.

‡ Prestwich in 'Journal,' vol. xii. p. 131.

§ The highest point above existing rivers at which Reindeer-remains have occurred in English *river*-gravel, so far as I know, is that of the Evesham gravel described by Mr. Ingram in vol. xxxv. of the 'Journal,' the surface of

the *Cyrena* yet lingered there, however, is doubtful*. If it be present in the fluvio-marine base of the sections at Menchecourt, in which the *Cyrena* occurs, it must have done so; but, as I have pointed out in the case of the gravel *g* overlying the *Cyrena*-sand at Uphall field, Ilford, a confusion of river-beds of distinct ages may very easily occur.

The passage upwards of this gravel *g* into a few feet of brickearth does not seem to occur, in the Thames valley, in those parts which are near to the areas from which this gravel, as well as *f* and the *Cyrena*-formation, have been denuded; and this doubtless arises from the partial denudation to which it has been subjected there; but the uniform way in which, where it does occur, this brickearth is distinct from, though successional to, the gravel beneath it, shows that it cannot be due, as has been suggested in the case of brickearth or loess generally, to floods each year swelling the rivers beyond their normal gravel-depositing condition; for were it so, the gravel would alternate throughout with thin seams of inundation-mud, instead, as is the case, of the two forming distinct beds. The presence of this brickearth in a thickness varying from 3 to 6 feet over and yet apparently gradually changing into the gravel, proves that some change of conditions occurred by which the formation of gravel gave place to mud; and it seems to indicate that a similar change took place in climate, as the minor glaciation waned, to that which took place as it came on; for the bed no. 4 of the *Cyrena*-formation in the Thames valley exactly resembles this brickearth over *g*, and succeeds the sand, no. 3 of that formation, in exactly the same way in which this brickearth succeeds the gravel *g*.

I observed in connexion with the *Cyrena*-formation that bed no. 4 of it seemed to indicate that a great flooding of the land-surface at that time occurred, which filled the water occupying the Thames valley with mud, and so gave rise by its precipitation to that bed. The same thing appears to have recurred at the end of the gravel *g*; for not only does this brickearth over it indicate this, but the bed γ in Lincolnshire (fig. LIV.) and the sands which I have referred to the action of the water from the ice of the Hessle Clay, and shown under the letters $\Gamma\gamma$ in fig. L., are overlain by a bed which I can only refer to this agency. The latter consists of a gravel (*gh*) several feet thick, principally made up of fragments of the hard Yorkshire chalk *worn flat*. The place which it occupies in the coast-section shows that its distribution is unconnected with the sands $\Gamma\gamma$, on which it rests, and that it is a sheet that has been formed in a small valley which stretches from Bridlington up to the Wold, and is occupied by a little stream called the Gipsey Race.

that gravel being stated as 60 feet above the Avon; and this would not, proportionately to the sea-level of the time, differ much from that indicated by the shingle in the Isle of Wight Foreland cliff. The skull and horns of a Reindeer are said to have occurred in gravel beneath Boulder-clay at Kilmaurs, in Ayrshire ('Journal,' vol. xxi. p. 216). This gravel, however, may have been contemporaneous with the overlying clay, supposing that to be of the minor glaciation, in the same way as the gravel *c* is with the Chalky Clay.

* See note, page 741.

The bed corresponding to this over γ in fig. LIV. is only about a foot thick, and is wholly composed of fragments of the limestone worn flat; and though the bed γ does not occur over the gravel of that district which corresponds to that in the Casewick cutting (gravel and sand not favouring the formation of that bed), this band of flat fragments does so occur in all the sections of gravel I met with, equally with those in which the bed γ appeared; and this on higher and lower elevations alike, and quite irrespective of valley configuration. It appears to me therefore that while in the valley of the Gipsey Race this flooding swept down these flattened fragments in quantity sufficient to accumulate a bed several feet thick, in the open country and on the low plateaux it accumulated them in quantity only sufficient to form this band a foot or so thick *. To flatten fragments in this way, the agent must have carried them over the surface without rolling them; and I can only conjecture, for want of a better explanation, that to do so the rain must have been so excessive as to have formed a sheet of water some inches thick over the general surface, which, while sufficient to impart motion to the fragments, was insufficient to roll them, but which, as it drained from the general surface into valleys, swept the flattened fragments in volume into these valleys, thus giving rise to the gravel *gh* in fig. L.

Whatever may be the true explanation, however, the beds of flattened fragments occupy precisely the same successional position to the atmospheric formation, γ, and to the sands, $\Gamma\gamma$, which I regard as synchronous with it, that the brickearth overlying the gravel *g* does to the river-formation, viz. that gravel which is synchronous with γ and $\Gamma\gamma$. It follows the irregular surface of γ under the humus.

The gravel marked *gh* in fig. XLIII., and shown as overlying the Hessle Clay in the Humber gorge at Ferriby, is probably of similar origin; for it contains many of the flat fragments of hard chalk, and patches of it occur over the Hessle Clay along the low ground east of the Wold in Sheets 85 and 86; but with this exception, and that of the very few and sporadic occurrences shown under the letters $\Gamma\gamma$ in figs. XLVII. and XLIX., and the continuous sheet shown under the same letters which extends from the edge of the Hessle Clay to Bridlington (fig. L.), all of which I have referred to the effluent water of the Hessle-Clay ice, no gravel or other accumulation posterior to the Hessle Clay in Lincolnshire or Yorkshire occurs but what seems to be of freshwater origin. These beds are shown in figs. XLVI. and XLIX. by the letter *h*; but the only instance, if indeed that be one, in which along the Holderness coast they yield fossils is, so far as I am aware, that of Hornsea, in fig. XLIX. At that place, near the railway-station, a gravel, very oblique-bedded, alternates with thin seams of loam, in which freshwater shells occur; and there we seem to get an instance of that annual flooding to which

* The angular drift recently described by Prof. Prestwich to the Society as covering the Lower-Chalk plain between Didcot and Chilton, containing reindeer and other mammalian remains and land-shells, seems to me to correspond either with this flooding, or with the atmospheric formation already described.

the formation of loess has been referred, and which is altogether different from that succession of gravel or sand by a thick bed of brick-earth, which obtains in the case of the gravel *g* and the *Cyrena*-formation. I am not, however, clear that the portion of the Hornsea gravel which yields shells may not be part of the *Cyrena*-formation accumulated before the depression converted it into marine gravel in Holderness *, as it seems from well-borings to descend below the present sea-level to a considerable depth, thus occupying a similar position to the freshwater part of the Clacton section as well as to the gravels which fill the partially submerged valleys penetrating the Lincolnshire coast beneath the marsh there, one of which was revealed by the borings and excavations for the Grimsby docks. The position, however, of the beds *h*, that are clearly posterior to the Hessle Clay (see figs. XLVI. and XLIX.), points to the sea-level on the eastern side of England having at the close of the minor glaciation been below that at which it now stands, and the land there to have extended somewhat, though perhaps to no very great distance, beyond the limit it now reaches; but in the north-west this was otherwise, for Mr. De Rance, in the twenty-seventh volume of the 'Journal' (p. 660), describes what he terms the postglacial sea (by which, as he does not make use of the term postglacial in the sense in which I have, he means the sea subsequent to the Upper Clay of the north-west) as having, after the emergence of the Upper Clay, occupied the very low plain between the rivers Mersey and Ribble which was skirted by low cliffs formed of that clay, and as having in this position deposited the "Shirley-Hill sand," described by him as underlying the main peat †; and he connects this with the sand containing marine shells at Rampside (shown in fig. LII. by the letter H) and with another bed west of Pilling, between Fleetwood and Lancaster, a few miles south of Rampside, which also contains marine shells and underlies the main peat. The sand shown by Mr. Mackintosh in the section he found disclosed by the Mersey-Dock excavations, which I have in fig. LIII. reduced from his representation, seems to be also the same formation; and this I have accordingly marked H. It therefore seems clear that in Lancashire and Cumberland the passing away of the minor glaciation took place before the sea-line had quite fallen to that position in which (by subsequent oscillation) it now stands; and it seems probable that this line in the north-west was about as much above that which it now occupies as it was below it in the east; for though Mr. George Maw, from whose short paper in the Geol. Mag. of 1869 (p. 72) I have reduced fig. LII., speaks of the bed I have marked H there as indicative of an elevation of the clay G', and its subsequent depression beneath the sea, it appears to me only to indicate that the

* I am not, however, aware that the *Cyrena* has occurred at Hornsea. The fossiliferous part of this gravel is near the railway-station.

† By this term of "main peat" Mr. De Rance explains that he means the peat which has been depressed beneath the present sea by the last movement of Britain, and is found beneath marine silt and salt water at many points round the coast, as mentioned in the sequel of this memoir.

extrusion of moraine from which G' originated ceased while low-water mark was still above the level of the bed H; and that thereupon mollusca established themselves upon this moraine, and their remains became imbedded in sands that accumulated in its hollows, in the same way that at an earlier period this occurred on the clay of the major glaciation at Dimlington, after the change in the inclination of England caused the ice to recede through the Humber and uncover that clay, only that the sands containing such remains there became mixed up in the moraine either from movements of the ice during this recession or from the passage of the Purple-clay ice over the place of them.

To what limit the present shores of England may have been extended beyond their present position by emergence subsequent to the point to which I have now traced this, there is nothing beyond the depth at which the land-surfaces round the coast (which are evidently connected with the surface of forest-growth under the marshes of our rivers) occur to afford any indication. The greatest depth of this kind appears to be that noticed by Mr. Rome and myself (in the paper in the twenty-fourth volume of the 'Journal,' already referred to), which the Grimsby-Dock works disclosed, and which was 52 feet below high-water mark of spring tides. The extension which this depth would indicate in connexion with so flat a coast as that of Lincolnshire is not inconsiderable, and of course the extension may have been far greater than this. I do not, however, imagine that it was so to any very great degree; but the depression, although it does not appear to have either increased or decreased in other parts of England since the Roman invasion, seems to be still proceeding in Cornwall, and on the coast of Brittany, it is said, has caused perceptible changes since that epoch.

Concluding Remarks.

Though many subjects of geological and palæontological importance are involved in the correct interpretation of the phenomena connected with the Newer Pliocene period, I confine the remarks which I have to make on them to the points specially touched by the sequence of events which I have traced in this memoir. These are:—1st, The coexistence of arboreal vegetation with the land-ice; 2ndly, The presence of the remains of *Hippopotamus* as indicative of interglacial periods; 3rdly, The existence of an open North Sea during the major glaciation; and, 4thly, The light furnished by the glaciation of England on theories of climate.

As to the first point, though land-ice is, in Greenland and Spitzbergen, accompanied by the absence of arboreal vegetation, this is not the case in the southern hemisphere, the ice-fields of South America escaping to the Straits of Magellan and to the channels of the west coast immediately north of that strait by glaciers which pass through a country that in parts is densely wooded. This seems to be in consequence of the greater precipitation in this region, Greenland, though so enveloped in ice, having, according to Rink, an

annual precipitation of snow only equal to 12 inches of rain. Cold merely, though as great, and even greater, than that of South Greenland, is not prohibitive of tree-growth, as we see by the limit of forests in Siberia, which reaches 10° of latitude to the north of South Greenland. The presence of trees, we may thus infer, is only regulated by their ability to ripen their seeds. This the summer of even South Greenland is adverse to, while from the high latitude of Spitzbergen the summer there, we may infer, is, under existing conditions, too short to allow it. The greater length of the summer, however, in England during the great glaciation, which the lower latitude must have involved, may have been as favourable to the ripening of the seeds of the most northern kinds of tree as that of Siberia now is, though, in consequence of the low range of the land and dryness of the climate, ice-fields do not occur in Siberia. The presence of arboreal remains in the Hoxne bed, mentioned by Prof. Prestwich, seems to me explicable only by trees having sprung up on the moraine of chalky clay as the plateaux covered with it became exposed by the diminution of the ice issuing in that direction, which, before its complete recession from the sea in East Anglia, became sufficient only to fill the valleys in the parts nearest to its issue there.

As to the second point, it seems to me that inasmuch as the Hippopotamus appears actually to have inhabited England during the Red Crag, its habits were not inconsistent with the freezing of rivers in winter. As some Bears hibernate, and as the habits of the Polar Bear are unlike those of other Bears, it is quite as reasonable to infer that the Newer Pliocene Hippopotamus of Europe had, in respect to frozen rivers, habits differing from those of its living African congener, as it is to assign to it the habit of migration, which is equally foreign to the living animal. To suppose that the Hippopotamus migrated a thousand miles or more every summer during the Glacial period appears to me, when its habits and powers are duly considered, improbable; and since from the presence in the base of the Red Crag of large tabular masses of unworn flint, many miles from the nearest chalk, we cannot doubt that the rivers, and even parts of the estuaries, were at that time frozen, the Hippopotamus, if it lived at that time, must have subsisted under those conditions. The remains of it found in those freshwater deposits on the North Norfolk coast beneath the sands *b1* and Till, which I regard as of the age of the Red Crag (and which would hardly be referred by any one to a time when a still milder climate than that of the Upper Crag prevailed), seem to me to prove that it did live where the rivers were thus frozen in winter, and that its habits must somehow have been conformable to those conditions. There is nothing yet made known, however, so far as I can make out, which points at all to its having inhabited England during any part of the great glaciation, none of the freshwater formations which appear to me to belong to the wane of this glaciation, such as those of Hoxne, Mildenhall, Brandon, Copford, &c., having, so far as I know, yielded its remains. It is the presence of its remains (gene-

rally more or less bouldered, however) in the gravel *g*, and in some few caves, in association with the remains of the Reindeer, that raises the presumption that it inhabited England during the minor glaciation, and synchronously with that Deer; but we have only to reflect on the case of existing Siberia to see how fallacious such association may be as evidence of the contemporaneous existence of two animals; for it is well known that the bones and tusks of the Mammoth are every summer washed out of the frozen soil of Siberia, on which that animal has long ceased to live, in as fresh a condition as those of the Reindeer which now die there, or as the antlers they yearly shed there can be; and that thus the remains of both animals must be swept into the gravels and other deposits now forming in the rivers there. So most probably was it the case in England during the minor glaciation, and the bones of the Hippopotamus, that undoubtedly inhabited this country during the first part of the *Cyrena*-formation, and which had become imbedded in that formation and in other superficial deposits of the same time, were during the minor glaciation washed out to intermingle in the gravel of that glaciation with the bones of the Mammoth which still continued to inhabit this country, and with those of the Reindeer, which about that time, it would seem, first made its way into it; and it is more likely that remains of the Hippopotamus, from some superficial bed of the *Cyrena*-period, became incorporated in the atmospheric formation which I have described as resulting from the thawing of the surface of the permanently frozen soil during the minor glaciation, and moving slowly over the surface and penetrating the fissures, so made their way into the few caves in which these remains have occurred, than that such an animal as the Hippopotamus should have frequented caves for shelter, or had its remains dragged thither by carnivorous animals or by man.

As to the third point, that of an open North Sea during the major glaciation, the possibility of it has been denied by one school of geologists, who explain the presence of molluscan remains in clays of morainic origin by the bed of this sea having been swept out by a vast ice-sheet coming from Scandinavia, which filled it. My study of the subject, however, has led me to the conclusion not only that the presence of molluscan remains in morainic clay did not originate in this way, but that throughout the glaciation the ice was of British origin solely, and the North Sea open*. The fact that where ice issues below the sea-level, moraine must be extruded in the unstratified form appears to have been overlooked, as well as the fact that floes bringing the remains of Mollusca from the shores to which they had frozen, and débris and blocks foreign to the area traversed by the ice giving rise to the moraine, pack against the face of the land-ice thus extruding; and so supply to that moraine material which every change in the terminal position of the ice must incor-

* That is to say, from the Norfolk coast southwards at least. The movement of the ice down the coast of Yorkshire and Lincolnshire to form the Purple Clay seems to indicate that there was land to the east of it at that time. Perhaps this was an extension of the island formed by North Norfolk shown in fig. VIII.

porate with it. The vast hypothesis involved in the filling of the North Sea by Scandinavian ice, and the thrusting out of its bed to supply molluscan remains to morainic clay in Scotland, so far from receiving support from these remains is rather negatived by them; for its advocates have not stopped to consider that the remains thus occurring are those *only* of shells now living in British seas, or in the Atlantic immediately north of the British Isles, and do not include even the two or three peculiar Crag species which survived into the earlier part of the period of the major glaciation, and are found in the lower part of the sands *b1* and at Bridlington, far less the many shells of the Upper Crag which had then disappeared from English seas. Yet the Red Crag, of the existence of which in Aberdeenshire, as well as Iceland, we get undoubted evidence, and which was the deposit of a part of the North Sea, shut in by land extending from Essex to Belgium, but open to the north, must have been represented by the unconsolidated bottom of the North Sea between Scandinavia and Britain immediately antecedent to this glaciation. How, therefore, if this was ploughed out, could the shells peculiar to the Crag have escaped being mixed up in the resulting moraine?

Lastly, as regards the fourth point, the cause of the great refrigeration of the Newer Pliocene period, it appears to me that neither the theory of Dr. Croll, nor those various modifications of it which have been advocated by Mr. A. R. Wallace, Mr. Murphy, and others, nor any theory based upon alterations in the distribution of land and water are reconcilable with the facts which the study of Newer Pliocene geology discloses. The single return of cold evidenced by the beds described by me under various representations of the letter g, and called by me those of the "minor glaciation," is only that which the continental geologists long ago detected in the second advance of the Alpine glaciers, and in no way bears out the successive alternations of warm and cold climate postulated by Dr. Croll and by some of the modifiers of his theory. Moreover, as it is conceded by Dr. Croll that the effect of the varying eccentricity in the earth's orbit, and the position of the aphelion point in connexion with it, would be *nil* but for the great (and indeed, he says, complete) diversion of the ocean-currents, which must, according to his contention, accompany it, it is evident that if this were the cause of the Glacial period, the isothermal lines of Western Europe and Eastern North America, the deflection of which is admitted to be due to the Gulf-stream, would not coincide with that proportional increase in cold in the respective continents which the evidences of glaciation indicate. Yet such coincidence is the case, and the same thing appears to hold good of the two sides of North America itself. Indeed from all the reports we get of glacial evidences in the American and Europæo-Asiatic continents, it seems that, saving the extension of the glaciers in mountains, the land-ice accumulated during the glaciations only in those regions which at the present time are the regions of greatest precipitation; and this, again, is inconsistent with any diversion of the ocean-currents or of the atmospheric circulation.

Whatever effect upon climate geographical changes may produce (and they are, it is by all conceded, considerable) it must be very slow; but though some refrigeration had been proceeding throughout the Older Pliocene period and the early part of the Newer, its culmination in the great glaciation appears to have been rapid. It is, moreover, inconceivable by me that changes so great as to have given rise to this should have passed away, *and again recurred* in the short interval between the major and minor glaciations. The insignificant depression of England traced in Stage VI. could have had no appreciable effect upon the climate of the northern hemisphere. Changes in land and water, if their sufficiency under any view of the case to produce a glaciation were conceded, must have been of an extent great enough to have altered the distribution of land and sea generally over the northern hemisphere; and it is, as I have said, inconceivable that these should, after giving rise to the great glaciation, have changed to those which restored the climate of the Upper Crag during the *Cyrena*-formation, and again changed to those giving rise to the arctic climate of the minor glaciation—a double coincidence—within the short duration, geologically speaking, of the Newer Pliocene period.

It is therefore, it seems to me, only a variation in the heat of the sun to which the glaciations can be attributed. When I expressed that opinion in a review of the climate controversy in the 'Geological Magazine' for 1876 (p. 451), no satisfactory cause for this variation had been suggested; but Dr. C. W. Siemens has now advanced the theory that the heat of the sun is maintained by the combustion of gases diffused in the medium through which it moves, and which are drawn in at the polar, and, after combustion, returned by centrifugal force from the equatorial parts of the sun into space. If this theory should prove well founded, it would furnish an explanation of this variation in the sun's heat, since the quantity of diffused gases may vary in different parts of the medium through which the sun moves, and the resulting combustion vary accordingly.

Postscript.

After the publication of the first part of this memoir (Q. J. G. S. vol. xxxvi.) I was anxious to reexamine the cliffs of Easton-Bavent, Southwold, and Dunwich (in the north part of Sheet 49); because, according to the view which I had there advanced, these cliffs are sections of the southern portion of that least submerged area, comprising all East Norfolk and North-east Suffolk, which earliest became land, and appears to me to have emerged up to and above its present level by the time when the ice of the Chalky Clay began to retire from East Anglia; and when all to the south and west of this (except so far as the ice extended and kept out the sea) still continued submerged up to those heights increasing southwards and westwards proportionally to the original increment of depression which I traced in that part of the memoir as indicated by the height above O.D. attained by the junction of the gravel *c* with the Chalky Clay overlying it; and I succeeded, though with some difficulty, in doing so.

I found that the bed which in the representation of Easton-Bavent cliff in the Introduction to the first Supplement to my father's 'Monograph of the Crag Mollusca' was shown as the Contorted Drift (7 of that representation, and *b 3* of this memoir), is really the moraine of a stream of ice which issued from the great inland ice-field at the close of the Chalky-Clay formation in East Suffolk, this moraine being a reconstruction of the Chillesford Clay on which it rests, and of some of the pebbly sand *b 1* which had covered that clay, and over which this ice-stream had passed*. Another of these (which in that representation was also shown in the Contorted Drift) cuts wedge-like into this sand on the higher part of the cliff near the dismantled homestead of Easton-Bavent; and a third cuts through these sands at the low south extremity of this cliff, near the part where they are bedded up to the early glacial island formed of Chillesford Clay, which is represented by the lower parts of Easton and Covehithe cliffs. This last-mentioned moraine runs down *below the beach*, and had a patch of Chalky Clay incorporated in it. At the north end of Southwold Cliff, near the marsh of the Buss Creek, is another of these moraines of sandy clay produced by the reconstruction of the pebbly sand, *b 1*, with some (probably Chillesford) clay; but this is overlain with chalky sand, like that mentioned in the sequel as occurring in the well-section, which, again, is overlain by a few feet of the ordinary Chalky Clay, and this, again, by brickearth from which considerable remains of an elephant were many years ago obtained; and the whole occupies and fills the southern edge of a trough that has been cut through the sands *b 1*, which form all the rest of the Southwold cliff, and which trough, to the north of the edge of it which is thus filled up, is now the marsh of the Buss Creek. It is evident to me that when these ice-streams went off from the main body of ice (which was but few miles inland, where the Chalky Clay in its usual form and thickness occupies the country with but little interruption as shown in Sheet 50 of Map 1), the sea-level was slightly, though not much, below its present position here, these ice-streams travelling to it. Whether the Brickearth with elephant remains accumulated in the same trough after this comparatively thin stream of ice ceased, but while yet the ice was issuing in glaciers through the main channels by which I have described it as issuing in East Anglia to the North Sea after its volume became too much reduced to cover the emerged plateaux there, and so be synchronous with the Hoxne brickearth, or whether it be a later deposit, I can see nothing to show.

I also found that the loam capping Dunwich cliff, that had for many years perplexed me, was not the Contorted Drift, as supposed in the first part of this memoir, but moraine of similar local origin to that just mentioned, with slight traces of the Chalky Clay and a few of its flints here and there in it; and that the whole of this cliff beneath it consisted of the sands *b 1* with great beds of shingle in them at the two extremities of the cliff, and a partial intercalation

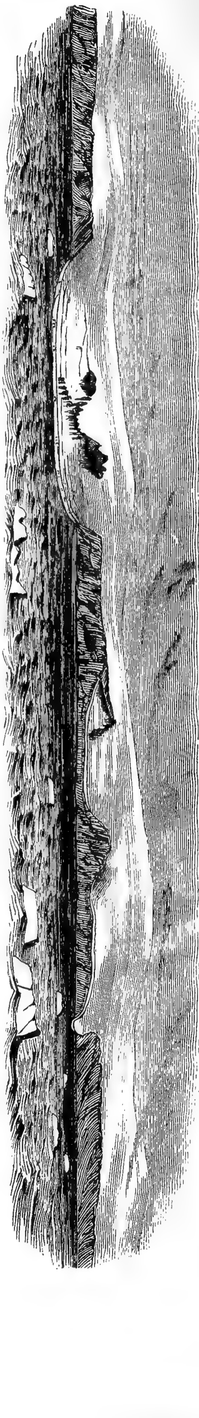
* This is adjoining Easton Broad; and a close inspection of it is necessary to see its distinctness from the Chillesford Clay on which it rests.

of a thin bed of clay near the north end, which was cut off by that shingle. No trace of the gravel *c* I found, however, appears, and the fluvio-marine Crag only shows itself by two small bosses rising through the beach near the south extremity of the cliff.

The evidences thus afforded of the ice at the time of its greatest extension in East Anglia streaming in no great thickness over the land nearest the sea, but lying in greater thickness a few miles inland, while its main outlet was by glaciers that descended below the sea-level of the time, and issued through the more considerable valleys of East Anglia as fiords, appear to me quite to coincide with the description given of the shores of Davis' Straits and Baffin's Bay in the Journal of the Society (vol. ix. p. 301), by Dr. Sutherland, whose illustration of a part of those shores, by permission of the Council, I here give.

We have only to substitute the low land and soft sands and clays of the East Anglian shore for the rocky soil and more elevated land of Baffin's Bay, over which, in Dr. Sutherland's representation, the ice in varying, but in no case great, thickness is streaming off from the thicker ice more inland, to form, in my opinion, an accurate idea of the shore (a little further eastward than the present) of North-east Suffolk at the time when the ice of the Chalky Clay reached its greatest extension, and before it shrank from the plateaux, to become

Cut x.—*Cliff-view, Cape York. Lat.* 76° N. *Length about* 10 *miles.* (From paper of Dr. P. C. Sutherland in vol. ix. of the Journal, p. 301.)



(Extract, p. 301.) "At Cape York, although the glacier there is the northward continuation of the glacier in Melville Bay, its protrusions into the sea (see *a* of fig.) never exceed 50 to 60 feet above the sea-level; and in some places it does not enter the sea in a continuous mass, but having descended over the brow of the cliff, it breaks off and slips down into the sea. * * * This is very well seen in the localities represented in the figure at *b* and *c*, where the free edge of the ice is upwards of 20 feet thick, and at least 100 feet above the sea-level."

near its issue confined to the valleys, which were then in *that part* of East Anglia a little above their present level. According to Dr. Sutherland, the main issue of the thick inland ice, from which the shallow sheets and streams that he shows in the cut as falling and welling over the cliffs come off, takes place through channels between the ice-buried islands of one of which the cliffs in his illustration are the section. Some of these channels he infers, from the length of fish-lines the Esquimaux use in fishing off the terminations of the glaciers that issue through them, descend 2400 feet below the sea-level, and are consequently filled with ice of that thickness. This is far in excess of the depth of the channels by which the issue of the ice of the Chalky Clay took place at the time which I have selected this representation to illustrate; for the principal one of these issue-channels in East Anglia, which is that of the Waveney and Yare (and which passed north of the island of which Easton-Bavent, Covehithe, Pakefield, and Hopton cliffs form a section), appears by the Yarmouth artesian well to descend only 170 feet below the present sea-level*. The wedge- or dyke-like small moraines that cut through the sands of Easton-Bavent are precisely of such a character as the small tongue of ice cutting down nearly to the sea on the right of Dr. Sutherland's figure would, I imagine, give rise to.

I also caused a well to be sunk last year upon the line of fig. I. (in the Plate to the first part of this memoir) where this crosses the Deben valley. The place of it is where the Chalky Clay (after covering the brickearth *b 3* of Hasketon kiln, and the gravel *c* bedded up to it) thins off on the brow of this valley. The well was 84 feet deep, and after passing through 2 feet of atmospheric formation, and 4 feet of the Chalky Clay, it traversed 12 feet of chalky sand and of grit with very small lumps of rolled chalk. This gradually changed into the gravel *c*, the upper part of which contained the shell-fragments described at p. 484 of the first part of this memoir, and much rolled chalk, both these fragments and the chalk gradually ceasing downwards. This gravel continued down to 75 feet, the last 9 feet only consisting of reddish-yellow sand, in the lower part of which were faint seams of comminuted Crag, and which sand may be either the Crag or, more probably, the base of the sand *b 1* containing these seams of material derived from the waste of the shores of the Crag beds up to and over which these sands were at the outset spread. Thus it is clear that the trough or channel of the Deben valley, which during the emergence had been washed by currents out of the sea-bottom formed of *b 1* and *b 3*, was, on its west side, completely filled up by an accumulation of the gravel *c* and of

* Many of the glacier-fiords by which this issue takes place in Greenland are, however, so shallow that boats can scarcely enter them. The Waveney issue probably took place partly by a fiord then constituted by Oulton Broad and Lothing Harbour, now filled in by more recent accumulations, so that the Waveney river has been barred out from entering the sea there, and diverted northwards into the Yare. The plunge of the Chalky Clay into this issue-channel is shown in the railway-cutting at Mutford. The plunge into the main issue-channel of the Yare is (or was) well shown by the section at Burg Castle brickfield.

this chalky grit to a greater thickness even than I have represented in fig. I., all of which, towards the centre of the valley, was, after it had laid the Chalky Clay (*d*) on this gravel and grit, ploughed out by the ice as it shrank into or thickened in that valley as emergence proceeded.

This chalk-grit evidently corresponds to the band of marl overlying the gravel *c* shown in fig. X[A]., and described at p. 488 of the first part of this memoir; and was produced by the washing out of the Chalky-Clay mud-bank by the ice-water immediately before this bank was precipitated into the sea along the shore.

I have also, since the publication of the first part, been fortunate in discovering a section disclosing distinctly the behaviour of the brickearth, *b 3*, to the sand *b 1* in East Suffolk. This is at Tuddenham, three miles N.E. of Ipswich; and there a denuded remnant of the lower part of this brickearth, about 8 feet thick, overlain by the gravel *c* (just as it is shown overlain along its denuded edge by this gravel in fig. I.), passes by alternate seams of brickearth and sand into the sand *b 1*, which underlies it in a thickness of about 15 feet, and rests on the London Clay, the Crag having either never existed there or been entirely removed. With the light thus thrown upon the subject, I infer that the break in the great subsidence, which in the first part of this memoir I thought might be indicated by the unconformity between the black sandy Till at Hasboro' and Bacton cliffs and the overlying stratified silt and clay, did not take place; and that the apparent unconformity must arise from this sandy Till, which is but very obscurely stratified, is nearly destitute of chalk (while the stratified silt and clay is full of it), and contains fragments and worn valves of the commoner shells of the sand *b 1*, being a morainic reconstruction of those sands by the first ice which reached Norfolk, soon after the commencement of the great depression submerged this shore of the Crag estuary, and which probably came from a more northerly direction than that which gave rise to the main mass of the Cromer Till, which, unlike this sandy Till, is full of chalk-débris. As this ice by its retreat before increasing submergence uncovered its moraine, the sea wore those hollows in its surface in which sands are bedded, and the whole then became covered by the horizontal and highly stratified mud full of chalk-débris and chalk-silt which spreads evenly over this unconformable surface, and probably was supplied by currents from the ice issuing through the Humber, of which the clay B is the moraine.

The shingly sands, *b 1*, at Southwold, immediately beneath the moraine at the north end of the cliff, described a few pages back, contain a seam of broken shells, which was also exposed in the railway-cutting a mile or so inland.

The species are exclusively those of the fluvio-marine Crag, and were, I consider, derived from it when, at the commencement of the formation of these sands, that Crag and the Chillesford Clay formed islands, and when in the channels around these islands those sands were first bedded. No trace of the characteristic shell of the lower part of those sands in Norfolk, *Tellina balthica*, could be detected in

this seam, but the sands containing this seam are, in my opinion, clearly no part of the Crag, and really unfossiliferous.

It is worthy of note that in this part, which is the region where the other evidence traced in the first part of this memoir shows the submergence to have been least, shingle-beds occur in the sand *b 1* from the top to the bottom; for these are evidence rather of shallow than of deep water.

[NOTE. *October* 1882.]—Since this memoir went to press, a description of some sections lately exposed at Stoke Newington has been given by Mr. Worthington Smith in 'Nature' of the 12th October, 1882. From these it appears that the *Cyrena* (*Corbicula*) does occur at that place, and up to an elevation there of about 68 feet above O.D. This is in bed B of Mr. Smith's section 4, which, with the sands overlying it, and marked C to F in his section, corresponds to bed ϕ 3 of my figures, and is overlain by alternations of sand and clay (G to M) forming the passage upwards to his bed N, which corresponds to my bed ϕ 4. This again is overlain and ravined by the atmospheric formation γ, which is bed Q of Mr. Smith's figure. The "floor," which Mr. Smith describes as containing palæolithic implements mixed with bones of Mammoth, Horse, Bison, and *Reindeer*, and with blocks and seams of transported London Clay, seems to occur at the horizon of the passage of ϕ 3 into ϕ 4, and thus to show that the Reindeer came in as the approach of the minor glaciation caused the severer climate from which the outpour of mud giving rise to ϕ4, and the transport of these seams and blocks of London Clay, proceeded. This is slightly above the part where the *Cyrena* ceases to occur in the section.

The duplication of this "floor" by a movement of subsidence, which Mr. Smith also shows, seems due to a step in the depression in which the *Cyrena*-formation originated; and as the horizon of this floor seems to me to coincide with that which carried the salt-water up the Somme valley to Menchecourt, where, according to Prof. Prestwich, the Reindeer occurs with the *Cyrena*, perhaps that shell lingered in France after it had ceased to live in England.

REFERENCE TO THE FIGURES AND MAPS WHICH ACCOMPANY BOTH PARTS OF THE MEMOIR, AND EXPLANATION THEREOF.

(Vol. XXXVI. Plate XXI. and Plate XXVI. of the present volume.)

The formations older than the Newer Pliocene are shown by Roman numerals, viz.:—

I. The Neocomian. II. The Gault and Upper Greensand. III. The Chalk. III'. The Chalk glaciated by the passage of the land-ice over it. IV. Thanet and Woolwich beds. V^A. Pebble-beds at base of London Clay. V. The London Clay. VI. The Bagshot series. VII. The Lower Oligocene. VIII. Pebble-beds, probably of Diestian (oldest Pliocene) age.

The beds of the Newer Pliocene series are indicated thus:—

Those of the Upper Crag (Stage I.).—*a 1*. Red Crag. *a 1'*. Fluvio-marine Crag. *a 2*. The Chillesford Clay.

Those of the great depression (Stage II.).—*b 1*. The Pebbly sand or Bure-valley beds. *b 2*. The Cromer Till. *b 3*. The Brickearth, which being contorted in the Cromer Cliff is there called the Contorted Drift. *b'*. Sand and gravel, representing *b 1*, *b 2*, *b 3* by extension of the submergence. B. The basement-clay of Holderness, synchronous with *b 2*.

Those of the rise from the great depression (Stages III., IV., and V.).—*c* (except in figs. XLVI. and XLVIII.) is sand and gravel, which, being a continuation of *b'*, was synchronous with the advance of the ice; and where it was below the sea as the ice approached it is composed of material from its moraine. *c*, in figs. XLVI. and XLVIII., represents sand-beds connected with the base of D. *d*. The Chalky clay. *e*. Sand and gravel synchronous with the retreat of the ice, and which, so far as emergence allowed the sea to enter the channels during this retreat, was deposited over *d*. *e'*. Gravel and sand formed terrestrially by the effluent water of the ice of the Chalky Clay. D. The Purple Clay of Yorkshire. D'. The Lower Clay of the North-west of England. *f*. Sand and gravel, being a continuation of *c* and *e*.

Those of the Cyrena-fluminalis *formation* (Stage VI.).—Φ. Fluvio-marine sand and gravel of Yorkshire. Φ'. Marine sand and gravel of the North-west of England. *ϕ*. The *Cyrena*-formation within the valleys of the Thames system; divided into—*ϕ* 1, Gravel occupying the river-bed before depression; *ϕ* 2, Stratified Brickearth with seams of sand and fine gravel, and containing freshwater shells; *ϕ* 3, False-bedded yellow sand with fine gravel, and containing freshwater shells in its lower part; *ϕ* 4, Brown brickearth without shells. At Clacton (fig. XXIV.) *ϕ* 2 is blue loam with land- and freshwater shells, being bed 6 of Geological Survey Memoir, and bed *d* of the section of Mr. O. Fisher, in vol. v. of the 'Geological Magazine,' p. 214; *ϕ* 2A, Dark brown peaty shale and greenish clay with valves of *Scrobicularia piperata*, valves of *Balanus*, opercula of *Bithinia tentaculata*, and pieces of wood, being bed 5 of Geological Survey Memoir, and bed *c* of Mr. Fisher's section; and *ϕ* 3 is sandy clay, containing *Cyrena fluminalis*, *Paludina lenta* (*P. clactoniensis* of 1st Supplement to 'Crag Mollusca'), and *Rissoa thermalis*, in association with *Cardium edule*, being bed 3 of Survey Memoir, and bed *b* of Mr. Fisher's section. I presume that it was from this bed or from *ϕ* 2A that all the salt-water shells, *Cardium edule*, *Scrobicularia piperata*, *Mytilus edulis*, *Tellina balthica*, *Tellina tenuis*, *Mactra ovalis*, and *Turritella communis*, which in the Geological Survey Memoir are given as from Clacton, were obtained. I possess all but the thee last named, collected from there by my father.

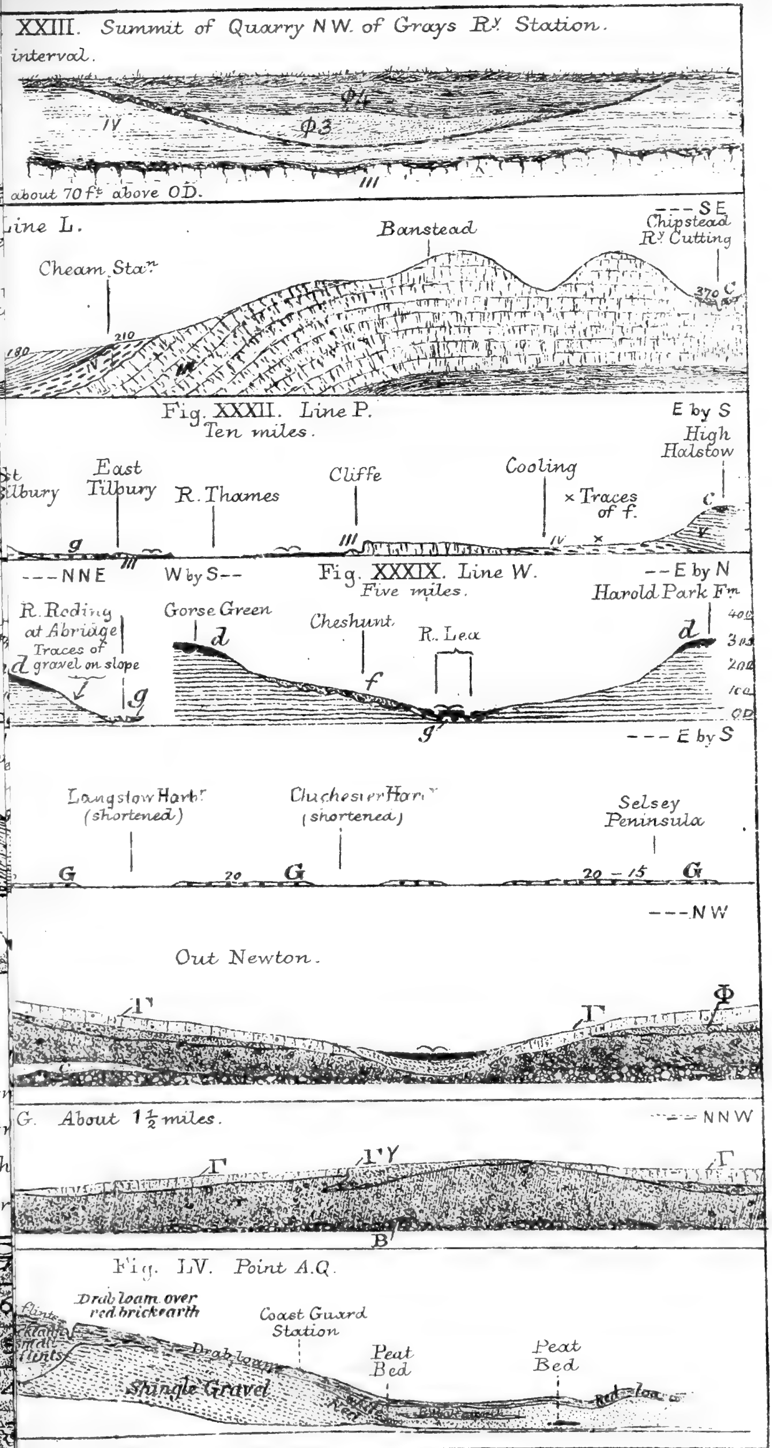
N.B.—In fig. VI. (in Plate to first part of Memoir) the whole *Cyrena*-formation at Grays is shown under letter *f"*.

Those of the Minor Glaciation (Stage VII.).—G. The marine gravel of Hants and Sussex with great blocks. G'. The Upper Clay of the North-west of England. Γ. The Hessle Clay. Γγ. Sand and gravel referred to the effluent water of the land-ice. γ. The atmospheric formation resulting from the thawing and refreezing of the uppermost part of the frozen land. *g*. River-gravel. γη. Band of flat fragments in Rutlandshire and South Lincolnshire. *gh*. Gravel with flattened fragments of hard chalk at Bridlington.

Those subsequent to the Minor Glaciation.—H. Marine sand of the North-west of England, which in fig. LII. contains molluscan remains. *h*. Fluviatile sand and gravel. ⏜. Recent beds and marsh clay.

The vertical scales are in feet above ordnance datum, signified by O. D.; H. W. signifying high-water mark. Elevations are in some cases written over the surface-line of the figures*. Figs. LI. and LII. are reduced from those of Mr. G. Maw, in vol. vi. of the 'Geological Magazine,' p. 72; fig. LIII. from that of Mr. Mackintosh in vol. xxxiii. of the Journal, p. 733; and fig. LV. from that

* I have had much difficulty in ascertaining elevations, the indications of them on the Ordnance Maps being confined to a few sheets, and these mostly in the north of England; but I have ascertained them sufficiently near for general purposes by obtaining the gradient profiles of most of the railways and allowing for differences between their datum-lines and ordnance datum. The ordnance book of levels is of but partial aid, being confined to certain main lines of road.



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MAPS AND SECTIONS OF THE NEWER PLIOCENE DEPOSITS IN ENGLAND

West, Newman & Co Photo-lith.

in the plate to Mr. Codrington's paper in vol. xxvi. of the Journal, the distinguishing letters being substituted to agree with those in this memoir.

The lines of figs. VI. and VII. (in the Plate to the first part of this memoir), XXI., XXII., XXVII., and of XXIX. to XLI. are shown by their indicating letters on Map 3; and that of fig. XXVIII. is shown in part on that map, but wholly in the continuation of Map 2. The lines of figs. I., III., V., VI., VII., VIII., IX. and XLII. are shown by their distinguishing letters on Map 2 or its continuation. The lines of figs. I., III., V., VI., VII., VIII. and IX., are also shown on Map 1. The places of figs. XLIII., XLIV., those of XLVI. to LIV., and those of the cuts Nos. iv. and v., are shown by their distinguishing letters on Map 5, and that of fig. LV. on the continuation of Map 2. Line A N in Map 3 is that of Prof. Hughes's figure, in cut No. ii.

The asterisk in Sheet 84 of Map 4 indicates the part where the Chalky Clay consists of reconstructed chalk, similar to the material of which most of the masses in the Contorted Drift in North Norfolk are composed.

The letters AP have by inadvertence been used to indicate one thing in Map 5, and a different thing in the continuation of Map 2; but the references to them in the body of the memoir will prevent any confusion between them.

The line marking on Map 4 the extreme limit of the Chalky Clay is shown as continuous, where known to me with exactness, and as broken where not; but in Map 3 it is, though exact, a broken line. The islands (partly in Sheet 46 and partly in Sheet 47) which are shown in Map 4 within this line, were not overwhelmed by the Chalky Clay until their size had been enlarged by emergence, as partly shown in Map 2, and not until the other islands shown in that map had emerged. The islands in Sheets 46, 13, and 7 of Map 4, not thus overwhelmed, are covered with the atmospheric formation of the major glaciation, viz., clay with flints and upland brickearth. Map 3 (which is an enlargement of the corresponding part of Map 2 in the greater detail which the larger scale of it allows, with the gravels *c*, *e*, and *f* shown in it as bedded in the channels around the islands) should be compared with the similar portion of Map 4, and it will be seen that the Colne channel came into existence by the coalescence into one island from emergence of the several small islands, shown in Sheets 7, 46, and 47 of Map 4, and by the origin from emergence of the islands to the east of the Channel, in Sheet 7. The ice as it reached this more lofty (coalesced) island to the west of the Channel, was checked by it, so that after overwhelming the two shown in Sheets 46 and 47 within the line (and which are enveloped by the Chalky Clay to their highest elevation, which is 550 feet above O.D.), it issued through this Channel in the way shown by the tongue-like projection of the broken line which marks the limit of the Chalky Clay there in Map 3. Somewhat earlier in the emergence it had issued by the Channel to the north of this island, which is shown in the centre of Sheet 46 of Map 2 (see Plate to first part of memoir) as extending over the water-parting between the Ivel, the Ouzell, and the Thame—patches of Chalky Clay occurring there which are delineated in Map 1; but its movement in this direction seems to have been arrested, while it was continued over the partings between the Ivel, Lea, and Colne*. It is at the extremity of this line in the Colne Channel at Birkett Wood, and at about 250 feet elevation, that the Chalky Clay underlain by the gravel *c*, is also overlain by the gravel *e*; the sea on the retreat of the ice having re-entered the Channel thus far from the south-westward.

In the south-east of Sheet 47 of Map 3 this line is shown as projecting tongue-like down the Blackwater Channel between the islands of Danbury and Tiptree, which, being covered with the gravel *b'*, do not appear in Map 4, but are shown as emerged in Map 3. This projection is made in order to include the patch of

* This arrest we may infer was caused by the resistance offered by the greater elevation of the parting between the Ivel and Ouzell, which is nearly 400 feet, while that of the parting between the Ivel and Lea by way of the Beane (which is the one that the Chalky Clay follows) is about 300 only, the elevations of all the partings by which the clay crosses from the Lea (Beane) to the Colne Channel, and which are all included within the lower plain of Mr. Hughes's section, p. 678, being under that also.

Chalky Clay (d) shown in fig. XL., the line of which figure crosses this channel to the south of fig. VII.; and it shows how the ice entering this channel and constricted by these two islands issued by it to the North Sea. The patch of Chalky Clay shown in fig. XL. being above the level to which from emergence the sea-line in this part had then fallen, the sea on re-entering this channel as the ice receded did not reach it, and it has therefore no gravel over it; but part of the same clay in fig. VII. being below that level, the sea covered this part with the gravel e, as shown in that figure. The ice also passed round the western side of Danbury Hill, against the lower part of which also, but beyond the limit of fig. XL., it has laid the Chalky Clay; and mounting the rest of the island, shown as extending through the centre of Sheet 1, of which Danbury Hill was the eastern promontory, it has covered much of it with its moraine of Chalky Clay up to the broken line which in Map 3 denotes the southern limit of that clay, illustrated by fig. VI.

The delineations of the gravels c, e, f, and g are, in Sheets 7 and 46, taken from the Geological Survey Maps (published and unpublished), as well as the line showing the limit of the Chalky Clay there*; but in the other sheets these are all taken from my own field-work. In Sheet 47 much of the gravel shown (except at the south-east extremity) is covered up by the Chalky Clay, and being exposed along the valley-edges and cut out of the valley-centres, it for the most part forms a fringe to the Chalky Clay along the valley-sides, but is intermitting in places.

The numbered divisions in all the maps are those of the one-inch scale Ordnance sheets; but by inadvertence the number 13 was inserted in two divisions of Map 1, that which is next to 12 on the left hand being No. 14. I find also that two or three of the small islands shown in the south-east of Sheet 54 of Map No. 2 should have been omitted, their elevation being below that which would correspond with the stage in the emergence intended to be represented.

Discussion.

Dr. Gwyn Jeffreys considered *Corbicula fluminalis* essentially a freshwater species, and that where, as at Kelsea Hill, it was found mixed with marine shells, the fact must be accounted for by the freshwater shells having been washed into the sea. He

* The only departure made by me from the survey representation (in which the gravel f is shown by a different colour from c and e) is in giving g distinct from f by elevation, the gravel shown by me under the dottings respectively indicating the gravels f and g being shown in the Survey Map as one. There are also a group of gravels shown in the Survey Map under a separate colour as "pebble gravel." These (which are omitted from Map 3) rest on the islands shown in that map on the east side of the Colne Channel; and that gravel which is comprised in Prof. Hughes's section at page 678, and called by him "Pebble gravel of the Higher Plain," is part of these. Most of this gravel is, like that in Prof. Hughes's section, the earlier part of the gravel c, which had emerged before the ice of the Chalky Clay reached it, and though composed chiefly of kidney-shaped flint pebbles, derived from the bed VIII. of my figures, contains a large proportion of quartz and quartzite pebbles also; but some of what is thus shown is, I think, not that gravel but bed VIII., which I am quite clear is not of Newer Pliocene age at all, and, I think, probably oldest Pliocene (Diestian), *i. e.* the shingle equivalent of the Lenham and Paddlesworth sands; and in this nearly every pebble is of flint. To keep in accord with the Geological Survey Map, I have shown in Map 3 the patch of gravel c at Finchley; but in my opinion this, like most of that coloured as pebble gravel, is the earlier part of c, which had emerged at the time represented by Map 3, and had the Chalky Clay laid upon it terrestrially; so that in order to show correctly the geographical conditions of the time, it should, I consider, be omitted from that map, and the black tint representing the island of Hampstead and Highgate Hill extended so as to include this part of the gravel and into connexion with the black tint to the north of it.

noticed the remarkable assemblage of southern forms of fossil Mollusca found at Selsea; and he questioned the former occurrence of glacial conditions in that part of England. He suggested that the deposit described in the paper ought to be called Posttertiary, and not Newer Pliocene.

Mr. Whitaker referred to the great value of the abstract supplied by Mr. Wood. He did not agree with the author that the Brandon brick-earths are interstratified with the Great Chalky Boulder-clay, but thought that the Boulder-clay underlying the brick-earth was a distinct deposit. The so-called "Hunstanton Gravel" is nothing but a mass of shingle and sand a little above the sea-level. He thought the brick-earth of the Nar to be of almost as modern age as the mud of the Thames. He was interested by the ingenious theory of sliding muds in Arctic regions.

In reply to Dr. Jeffreys he pointed out that *Corbicula fluminalis* occurs in the Crag. He thought that the range of species might have been very different in former times from what it is at present. Mr. S. V. Wood had found Mediterranean shells in deposits which were undoubtedly of glacial age. He remarked upon the difficulty of drawing a line between the Pliocene and Drift deposits, and expressed his sense of the great value of these researches of Mr. Wood.

Prof. Seeley admitted that the gravels of Hunstanton (which he had first described) exhibited in places beach-conditions, but they graduated into estuarine and freshwater deposits. He thought Mr. Wood had not sufficiently taken into account the necessarily local characters of many of these gravel deposits in relation to the contours of existing valleys while estuaries were disappearing from them, and when many parts of the country were at different levels relatively to what now obtains.

Mr. Koch stated that he had seen in Norway, during changes of wind, masses of ice, containing shells frozen into it, sometimes carried 60 or 70 miles down the fiords.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1881–82.

November 2, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Richard Paley Gardner, Esq., Dytchleys, Southweald, near Brentwood, Essex; Henry Neville Hutchinson, Esq., B.A., 14 Canynge Road, Clifton, Bristol; Henry Johnson, Esq., Dudley; William Regester, Esq., F.C.S., Lawn Lodge, Isleworth, Middlesex; and George Tate, Esq., Ph.D., College of Chemistry, Liverpool, were elected Fellows of the Society.

The List of Donations to the Library was read.

A specimen of *Neuropteris heterophylla*, from the New Winning Sydney Mines, Cape Breton, Nova Scotia, was presented to the Museum by C. B. Brown, Esq., F.G.S.

Prof. Hughes called the attention of the Society to the work being done by the Swiss Palæontographical Society. He pointed out that, the Swiss being a small nation and their scientific men proportionately few in number, it was a very spirited thing of them to keep up the regular publication of a series of exhaustive treatises on the plan of our own Palæontographical Memoirs. Those engaged in palæontological work knew well the value of these publications, and could appreciate the labour and care necessary to keep going such a large undertaking. He felt sure that much more support could, and would, be offered to our Swiss fellow labourers

and our good friend Renevier if the English public could be made aware of the important work they were doing. He therefore invited the cooperation of the members of the Society in the matter.

The President announced that at the next Meeting of the Society Prof. Hughes would state what were the general results achieved by the International Geological Congress held this year at Bologna.

The following communications were read :—

1. "On the Genus *Stoliczkaria*, Dunc., and its Distinctness from *Parkeria*, Carp. and Brady." By Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S., Pres. R.M.S.

2. "On the Elasticity- and Strength-constants of Japanese Rocks." By Thomas Gray, Esq., B.Sc., F.R.S.E., and John Milne, Esq., F.G.S.

3. "The Glacial Deposits of West Cumberland." By J. D. Kendall, Esq., C.E., F.G.S.*

Specimens and microscopic sections of the genus *Stoliczkaria* &c., were exhibited by Prof. P. M. Duncan, F.R.S., in illustration of his paper.

November 16, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

Prof. Hughes said that he proposed to issue to the Committee of organization for Great Britain a full Report of the proceedings of the Bologna Congress; but in anticipation of that, he begged to offer to the Geological Society a brief statement of the results.

It would be within the recollectien of the Fellows of the Society that, at the Geological Congress of Paris in 1878, two principal subjects were proposed for discussion at the Bologna Congress, and each was referred to an International Commission named by the Congress :—

1. The Unification of Geological Nomenclature.
2. Geological Cartography.

On the 2nd April, 1880, the International Commission for the Unification of Geological Nomenclature was convened at Paris by the President of the Paris Congress and the President elect of the

* This paper has been withdrawn by permission of the Council.

Bologna Congress; and the Commissioners present at that meeting, having regard to the impossibility of drawing up any thing like a complete report upon so vast a subject before the meeting of the Congress, and feeling that there would be much advantage gained by settling the meaning of the terms commonly used to designate the larger and smaller divisions of the materials which make up the crust of the earth, and the portions of time to which they are assigned, recommended that, first of all, those questions of a general character should be considered, such as the definition of epoch, period, formation, rock, &c. &c. A *résumé* of the reports of the different nationalities was drawn up by the General Secretary, M. Dewalque, and presented to the Congress, and the discussion was taken upon it. America and England were regarded as one from the very first, a happy result of the friendly feeling that exists on all points between the two nations, and at Bologna cordially upheld by their distinguished guest of that evening, Dr. Sterry Hunt.

The conclusions arrived at were briefly—that the term Group should be applied to the largest geological division of rocks, System to the next, Series to the third in order of magnitude, Stage to the fourth, and the French word "Assise" was placed in the fifth place, it being left to other nationalities to use whatever word in their own tongue seemed most conveniently to represent this smallest defined term. The Time-words were, in descending order of magnitude, Era, Period, Epoch, Age—Era corresponding to Group, Period to System, Epoch to Series, Age to Stage. It was pointed out that the German and English use of the word *formation* for a set of deposits which it was desired to group together under one head, *e. g.* Carboniferous formation, could not be adopted by the French, with whom this word always had reference to the origin of the mass, and was considered an abbreviation of the "*mode of formation.*" This had been already fully recognized by the English Committee, in the minutes of one of the meetings of which the following resolution appears:—"The term Formation having been used by Continental geologists to denote the action by which a thing is formed, and its mode of formation, and its use in the sense accepted in England being given up in America, the Committee recommend that the term be employed as rarely as possible in the English sense, and that such words as group, rock, bed, &c. be substituted for it." It was pointed out by the German geologists that there were many nations who could not adopt "terrain;" and therefore this word also was excluded from the more strictly defined terms. MM. Beyrich and Von Möller explained that the word *series* could not be conveniently introduced into German or Russian; and it was therefore agreed that the words *section* and *Abtheilung* should be admitted as synonyms of *series*. It will be observed that there is a consistency in the group of words adopted in English, they are all what may be called synthetic; the analytic words, such as division, subdivision, section, &c., remain undefined.

Prof. Hughes regretted they were not able to transpose the words Group and Series, as it certainly would be more convenient to use

series for the larger, and *group* for the smaller division; but it was not a matter of great importance.

In the course of the discussion, various speakers pointed out, by way of illustration, what they would include under these different heads; and it was clear that there was very much to be done before any equivalent value could be attached to the subdivisions of different ages, or of the same general age, in widely separated areas.

The English Committee had commenced work upon this question, and he had laid before the Congress the Reports of the Subcommittees which had furnished him with the results of their inquiries, as well as some special Reports forwarded to him by individuals. The Congress did not, however, pass on to the discussion of these matters; but the manner in which the English Committee were organizing their work met with the approval of the Congress, and a vote was passed that the other countries should adopt a similar plan, and form subcommittees for the investigation of the several groups. He was further unofficially requested to get the Reports printed as soon as possible, in order to facilitate discussion, and with a view to arriving at an understanding upon the simpler questions before the next Meeting of the Congress. This was appointed to be held at Berlin in 1884. The following Congress will be held in England.

Dr. T. Sterry Hunt gave some account of the pre-Cambrian or Eozoic rocks of Europe as compared with those of North America. He had on several occasions studied the former, both on the continent and in the British Isles, especially with Dr. Hicks in Wales in 1878. In North America the recognized base is a highly granitoid gneiss, without observed limestones, which he has called the Ottawa gneiss, overlain, probably unconformably, by the Grenville series of Logan, consisting chiefly of granitoid gneisses, with crystalline limestones and quartzites. These two divisions made up the Laurentian of Canada, and correspond respectively to the Lewisian and the Dimetian of Hicks. Resting in discordance on the Laurentian we find areas of the Norian or Labrador series (Upper Laurentian of Logan), chiefly made up of anortholite rocks, granitoid or gneissoid in texture, with some true gneisses. The Huronian is seen to rest unconformably on the Laurentian, fragments of which abound in the Huronian conglomerates. To the lower portion of the Huronian the speaker had formerly referred a great series of petrosilex or hälleflinta rocks, described as inchoate gneisses, passing into petrosilex-porphyries, occasionally interstratified with quartzites. This series, in many places wanting both in Europe and America, he is now satisfied forms an underlying unconformable group—the Arvonian of Hicks. Above the Huronian is the great Montalban series, consisting of grey tender gneisses and quartzose-schists, both abounding in muscovite, occasionally with hornblendic rocks. The Pebidian of Hicks includes both the Huronian and the Montalban; to which latter belong, according to the speaker, certain gneisses and mica-schists both in Scotland and in Ireland, as he had many

years since pointed out. In some parts of North America he found the Montalban resting unconformably on Laurentian. Above the Montalban comes the Taconian (Lower Taconic of Emmons), a series of quartzites and soft micaceous schists, with dolomites and marbles. All these various series are older than the Lower Cambrian (Menevian) strata of North America; and it may be added that the Keweenian or great copper-bearing series of Lake Superior there occupies a position between the Montalban and the Cambrian.

In the Alps the speaker recognizes the Laurentian, Huronian, and Montalban, all of which he has lately seen in the Biellese, at the foot of Mount Viso, in Piedmont. The Huronian is the great *pietre verdi* group of the Italians; and much of what has been called altered Trias in this region is, in his opinion, probably Taconian. The Montalban forms the southern slope of Mont St. Gothard, and is the muscovite gneiss and mica-schist of the Saxon Erzgebirge. Here Dr. Credner and his assistants of the Geological Survey have described abundant conglomerates holding pebbles of Laurentian rocks imbedded in the Upper or Montalban gneiss. The pre-Cambrian age of this has been shown by Credner, who has proved by careful survey that the so-called younger or Palæozoic gneisses of Naumann are really but a continuous part of the older series. Late surveys also show that the crystalline rocks of the Taunus are really Eozoic and not, as formerly maintained, Devonian in age.

The speaker insisted upon the fact that where newer strata are in unconformable contact with older ones, the effect of lateral movements of compression, involving the two series, is generally to cause the newer and more yielding strata to dip towards and even beneath the edges of the older rock, a result due to folds, often with inversion, sometimes passing into faults. This phenomenon throws much light on the supposed recency of many crystalline schists.

The following communications were read:—

1. "Additional Evidence on the Land-Plants from the Pen-y-glog Slate-quarry, near Corwen." By Henry Hicks, Esq., M.D., F.G.S.

2. "Notes on *Prototaxites* and *Pachytheca* from the Denbighshire Grits of Corwen, North Wales." By Principal Dawson, LL.D., F.R.S., F.G.S.

The following specimens were exhibited:—

Land-plants from the Pen-y-glog Slate-quarry, near Corwen, exhibited by Dr. Hicks in illustration of his paper.

A specimen of *Prototaxites* from Bay de Chaleurs, and specimens of *Pachytheca* from Rumney, exhibited by W. Carruthers, Esq., F.R.S., F.G.S.

Two sections of *Pachytheca*, exhibited by W. T. Thiselton Dyer, Esq., F.R.S.

A specimen of Lithiophilite from Branchville, Conn., U.S.A., exhibited by H. Bauerman, Esq., F.G.S.

Pebbles of ancient gneiss from a conglomerate in the gneiss and mica-schist formation of the Erzgebirge, and a specimen of the so-called *Eopteris Morierei*, Saporta, from the slates of Angers, exhibited by Dr. T. Sterry Hunt, F.R.S.

Welsh pre-Cambrian rock-specimens, exhibited by Prof. T. McK. Hughes, M.A., F.G.S.

December 7, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

William Amhurst Tyssen Amherst, Esq., M.P., F.S.A., Didlington Hall, Norfolk, and 88 Brook Street, W.; Robert Edward Cresswell, Esq., Assoc. Mem. Inst. C.E., Uttoxeter Road, Derby; W. R. Eaton Hodgkinson, Esq., Normal School of Science, South Kensington, S.W.; Simon D. Macdonald, Esq., 264 Gottingen Street, Halifax, Nova Scotia; Rev. Edward Cook Pritchard, Bourne House, Brook Street, Peterborough; Rev. Alexander Simpson, B.Sc., B.A., Torry, Aberdeen; Prof. William Waagen, Ph.D., Mariengasse 2B, Prag, ii.; Frederick John Webb, Esq., 22 St. James Place, Plymouth; and Charles Henry Wilson, Esq., M.A., Rugby, Morgan County, Tennessee, U.S., were elected Fellows of the Society.

The Secretary announced that the original drawings of fossil fishes, made from specimens in the collection of the Earl of Enniskillen and bequeathed to the Society by the late Sir Philip Egerton, had been received.

The List of Donations to the Library was read.

Mr. W. Topley made the following further statement respecting the International Geological Congress at Bologna:—

Prof. Hughes's communication to this Society, at its last Meeting, referred to the work done at the Congress upon Geological Nomenclature. The present communication refers to the second subject debated by the Congress, the Unification of Colours, Signs, &c. employed on Geological Maps.

At the Congress held at Paris in 1878 certain geologists in each country were appointed Presidents of Committees, to be thereafter nominated by them. Sir Andrew Ramsay is the President of the British Committee. Last year a Committee was nominated of fifteen members, several Meetings of which were held in London.

The final Report was drawn up at York, and was submitted to the Congress at Bologna. This Report has been printed in the 'Geological Magazine' (Dec. ii. vol. viii. p. 557, 1881). A brief account of the Committee's work was read before Section C, and is printed in abstract in the British Association Report.

The object of the Congress in discussing this question is to secure, if possible, a greater uniformity than heretofore in the geological maps of various countries; and to this end it has recommended the adoption of a scheme of colours and signs, which it is hoped may be used, with but little modification, by all nations. There is no intention of even recommending the adoption of this scheme by Surveys now in progress, maps of which have been partly published on any other system. But for general maps, which may hereafter be published, it may well be used, and perhaps also for some national surveys. The Italian Survey is about to publish its maps, and hopes to adopt the scheme recommended by the Congress. The Indian Survey, being about to issue a connected series of maps, would like to do the same. The United-States Geological Survey is also now engaged in the consideration of this question.

The recommendations finally adopted, as regards colour, were as follows:—

Groups or Systems.	Colours.
Crystalline rocks of Pre-Cambrian age..	Bright rose-carmine.
Crystalline rocks of unknown age......	Pale rose-carmine.
Palæozoic	(Question reserved for Map Committee.)
Trias	Violet.
Lias	Dark blue.
Jurassic	Blue.
Cretaceous	Green.
Tertiary	Yellow.
Eruptive rocks	(Question reserved.)

The subdivisions of groups or systems should be shown by various shades of the colour adopted, the darker shades denoting the older beds. Coloured lines or "reserves" of white can also be employed when the map is printed in colours.

The letter denoting the group or system should be the initial Roman capital of its name, most of these names being now in almost universal use. The letter of the smaller divisions (series, stages, and beds) should be the small initial letter of the name. Still smaller subdivisions should be marked by figures, the lowest being denoted by 1.

Examples:—

Silurian	S.
,, Ludlow	Sl.
,, Lower Ludlow	Sl^1.

The Eruptive Rocks should be marked with the Greek capital letter of the name.

The Congress resolved to prepare and publish a geological map of Europe, correlating, as far as possible, the work of the various national surveys and that of independent observers. The discussion of the details of this question was referred to a Commission, consisting of the President, Vice-Presidents, and a few other members of the Congress.

Of this Commission Prof. Daubrée was President and Prof. Dewalque Secretary; the latter has printed a report of its proceedings (Liége, 1881, pp. 16).

The Commission recommended that the map should be published at Berlin, on the scale of 1:1,500,000 (about 25 miles to one inch). This map will require 50 sheets, and will be so arranged that any number of the sheets can be mounted together to show any required area. The complete map will be about 12 feet by 10 feet. Much discussion took place as to the constitution of the Committee which should be intrusted with the work. The Commission finally recommended that representatives of five countries would suffice. In voting upon which those countries should be, Great Britain received the votes of all, France coming next, Germany third, Russia fourth. A second ballot being taken for the fifth country, Austro-Hungary was chosen.

The cost of preparing the map at Berlin is estimated at about £2500. The various governments of Europe will be asked to contribute to this—the eight larger countries in equal proportions, about £280 each, the ninth part being divided amongst some of the smaller States.

These recommendations were adopted by the Congress, with some modification as regards the number of the Committee, which now stands thus:—

Austro-Hungary	Dr. E. von Mojsisovics.
France	Prof. Daubrée.
Germany	Dr. E. Beyrich (Director) and W. Hauchecorne (Assistant Director).
Great Britain	W. Topley.
Italy.................	F. Giordano.
Russia	Prof. von Möller.
Switzerland	Prof. Renevier (Secretary).

Each member of the Committee is to supply a map of the country allotted to him on the required scale, and ready for engraving at Berlin, where the topographical map is already in preparation.

In the cases of countries not directly represented on the Committee, arrangements will subsequently be made for obtaining the required information. But some such arrangements were then agreed to, and Austria will supply the geology of Turkey. Parts of Africa and Asia come within the map. Of these, France will supply

the information for Algeria. Up to the present time the best geological account of Palestine is that published by Lartet; and France would therefore naturally take charge of this country. But, as the English Palestine-Exploration Society has just published a map of the country, on the 1-inch scale, and probably possesses a considerable amount of geological information in the reports and note-books of its surveying officers, it was arranged that the representative of Great Britain should take charge of it.

The "language" of the map will be French; but translations of legends, explanations, indexes, &c. will be given in the language of the country to which they refer. All names of places will be written as is usual in the country to which they belong.

Several questions were reserved for the consideration of the Map Committee, as, for example, the colouring of the Palæozoic rocks, and the meridian to be used for the map. As regards this last, it was understood that for a general map of Europe the meridian must be either Greenwich or Ferro.

Many questions respecting classification, nomenclature, &c. will arise during the progress of the work. For the discussing of these, a second Committee was elected to cooperate, when necessary, with the Map Committee; the Members were chosen for the most part from the Vice-Presidents. Prof. Hughes is the member for England.

The next meeting of the Congress is fixed for 1884, at Berlin, by which date it is hoped the Map will be ready for publication. Preliminary meetings of the Committees are fixed for 1882 at Foix (at the country meeting of the Geological Society of France), and, for 1883, in Switzerland.

Prof. Judd, at the request of Professor John Milne, F.G.S., of the Imperial Engineering College of Tokio, Japan, called the attention of the members of the Society to the important work now being carried on by the Seismological Society of Japan. The objects at which this Society chiefly aimed were:—(1) the preparation from ancient Japanese records of a reliable Earthquake-Catalogue; (2) the testing of various instruments devised for seismographical inquiries; (3) the careful observation, at as many points as possible, of the elements of the earthquake-movements; (4) the measurement of the amount of elevation and depression of areas during earthquake-shocks. Already, by the labours of this Society, seismographs had been supplied to many of the telegraphic stations in Japan, and valuable results had been obtained. The Seismological Society of Japan was founded before that of Switzerland. Geologists could become members of the Seismological Society of Japan (which stands greatly in need of help) by an annual payment of £1, which will entitle them to receive the whole of the publications of the Society. Prof. Judd was prepared to receive the names of members on behalf of Prof. Milne.

The following communications were read :—

1. "The Zones of the Blackdown Beds and their Correlation with those at Haldon, with a List of the Fossils." By the Rev. W. Downes, B.A., F.G.S.

2. "On some new or little-known Jurassic Crinoids." By P. Herbert Carpenter, Esq., M.A. Communicated by Prof. P. Martin Duncan, M.B.Lond., F.R.S., F.G.S.

3. "Notes on the Polyzoa of the Wenlock Shales, Wenlock Limestone and Shales over the Wenlock Limestone. From material supplied by G. Maw, Esq., F.L.S., F.G.S." By G. R. Vine, Esq. Communicated by Dr. H. C. Sorby, F.R.S., V.P.G.S.

The following specimens were exhibited :—

Greensand Corals, from Haldon, exhibited by A. Champernowne, Esq., F.G.S.

A series of Specimens, exhibited by the Rev. W. Downes in illustration of his paper.

December 21, 1881.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Charles Duffin Barstow, Esq., Garrow Hill, York; and Joseph Lundy, Esq., Marlborough House, Slough, Bucks, and St. Mark's Road, Windsor, were elected Fellows, and Professor E. D. Cope, of Philadelphia, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "The Torridon Sandstone in relation to the Ordovician Rocks of the Northern Highlands." By C. Callaway, Esq., M.A., D.Sc., F.G.S.

2. "The Pre-Cambrian (Archæan) Rocks of Shropshire." Part II. By C. Callaway, Esq., D.Sc., F.G.S.

3. "The Red Sands of the Arabian Desert." By J. A. Phillips, Esq., F.R.S., F.G.S.

4. "Analyses of five rocks from the Charnwood Forest district." By E. E. Berry, Esq. Communicated, with Notes, by Prof. T. G. Bonney, F.R.S., Sec.G.S.

The following specimens were exhibited:—

A specimen of Opal from Bullo River, Queensland, exhibited by Prof. T. G. Bonney, F.R.S., Sec.G.S.

Rock-sections and specimens, exhibited by Dr. Callaway, in illustration of his paper on the Pre-Cambrians of Shropshire.

Specimens of sand from the Arabian Desert and from the Millet-seed Sandstone of Lancashire and Cheshire, exhibited by J. Arthur Phillips, Esq., F.R.S., in illustration of his paper.

January 11, 1882.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

W. J. Clunies Ross, Esq., B.Sc. Lond., 4 Trinity Terrace, Bow; Joseph William Brown, Esq., C.E., 40 Frederick Road, Aston, Birmingham; William Hunter, Esq., 8 Queen Anne's Gate, Westminster, S.W., and Briton Ferry House, Briton Ferry, South Wales; Henry Tomlison, Esq., M.Inst.C.E., The Woodlands, Cambridge; and Charles Otto Trechmann, Esq., Ph.D., Town Wall, Hartlepool, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Chalk-masses or Boulders included in the Contorted Drift of Cromer, their Origin and Mode of Transport." By T. Mellard Reade, Esq., F.G.S.

2. "Observations on the two Types of Cambrian Beds of the British Isles (the Caledonian and Hiberno-Cambrian), and the Conditions under which they were respectively deposited." By Prof. Edward Hull, LL.D., F.R.S., F.G.S.

3. "The Devono-Silurian Formation." By Prof. E. Hull, LL.D., F.R.S., F.G.S.

January 25, 1882.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

John Blaikie, Esq., Bridge House, Newcastle, Staffordshire; M. Ernest Jobling, Esq., South Tawton, Devonshire; and the Rev.

Stanley A. Pelly, B.A., Thorncliffe, Saltford, near Bristol, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On the Fossil Fish-remains from the Armagh Limestone in the Collection of the Earl of Enniskillen." By James W. Davis, Esq., F.G.S., F.L.S.

[Abstract *.]

The author described in this paper a large collection of fossil fish-remains preserved at Florence Court, Enniskillen, but soon to be removed to the new Natural History Museum in the Cromwell Road. The collection comprises, besides specimens collected by the Earl of Enniskillen from the Carboniferous Limestone of Armagh, a large series acquired from the famous collection of the late Captain Jones, M.P. Several genera and species were described by Prof. Agassiz in his 'Recherches sur les Poissons Fossiles' (1833–43), and again referred to by General J. E. Portlock, F.R.S., in his 'Report of the Geology of Londonderry and parts of Tyrone and Fermanagh' (1843).

In 1854 Prof. M'Coy described many new genera and species in his work on the 'British Palæozoic Rocks and Fossils,' principally derived from a study of the portion of Capt. Jones's collection deposited in the Cambridge Museum. Prof. Agassiz paid a visit to Florence Court in 1858, and appended names to some of the fossil teeth in Lord Enniskillen's cabinets, intending to describe and figure the new forms, and to revise the whole of his former work. His death prevented this intention from being carried into effect. As far as possible the determinations of Prof. Agassiz have been adhered to in the present paper.

The detached and isolated condition in which the remains are found renders any appreciation of the relationship of the teeth and spines, or even of the teeth only, to each other extremely uncertain and difficult. Some speculations as to the probable organization and characteristics of the Carboniferous fishes which they represent, evolved during a long consideration of the specimens, have therefore been postponed to a future opportunity.

The following is a list of the genera and species described in the paper:—

Ctenacanthus plicatilis, *C. dubius*, *C. lævis*, *C. pustulatus*, *C. tuberculatus*, *Compsacanthus carinatus*, *Cosmacanthus marginatus*, *C. carinatus*, *Lispacanthus retrogradus*, *Cladacanthus paradoxus*, *C. major*, *Gnathacanthus triangularis*, *Cladodus polyodon*, *C. curvus*, *C. destructor*, *Carcharopsis Colei*, *Copodus cornutus*, *C. furcatus*, *C. spatulatus*,

* This paper has been withdrawn by the Author for publication elsewhere.

C. minimus, Lobodus prototypus, L. planus, Mesogomphus lingua, Pleuragomphus auriculatus, Rhymodus transversus, R. oblongus, Characodus angulatus, C. lunatus, Pinacodus gonoplax, P. gelasi, Dimyleus Woodi, Mylax batoides, Mylacodus quadratus, M. Sesarma, Homalodus trapeziformis, H. quadratus, Petalodus quadratus, P. recurvus, P. inæquilateralis, Polyrhizodus magnus, P. Colei, P. elongatus, P. sinuosus, P. attenuatus, P. constrictus, Chomatodus linearis, C. acutus, Glossodus marginatus, Harpacodus dentatus, H. clavatus, Streblodus oblongus, S. Colei, S. Egertoni, Deltodus sublævis, D. expansus, D. nobilis, Deltoptychius acutus, D. gibberulus, Sandalodus Morrisii, Psephodus magnus, Pœcilodus Jonesii, P. gibbosus, Tomodus convexus, Xystrodus striatus, X. angustus, X. Egertoni, Helodus crassus, H. tenuis, H. clavatus, H. dilatatus, H. acutus, H. richmondensis, H. triangularis, H. biconus, H. expansus, Rhamphodus dispar, Petalorhynchus psittacinus, Pristodus falcatus.

Discussion.

Prof. Seeley suggested that in the fang-like portions of the teeth in *Polyrhizodus* we have indications of an analogy with the Rays, and that the teeth may have followed each other in series. He thought that many forms relegated to different genera and species might belong to the same palate. He spoke of a similar variety of form being exhibited in the teeth referred to *Cochliodus*. He referred to the difficulty of dealing with the remains which had been thought to be allied to the *Diodon*.

The President testified to the great labour undertaken by Mr. Davis in investigating the large collection of fossils brought together by the Earl of Enniskillen. Apart from the determination of the analogies of these forms, the naming and description of these characteristic fossils would be of great service to stratigraphical geologists.

The Author admitted that some of the forms described might belong to the same palate; but until actual evidence of this was produced, he maintained that they ought to be described and receive distinctive names. Many of the names had been attached to these fossils by Agassiz. He mentioned the discovery of Worthen that the teeth referred to the genera *Cochliodus* and *Helodus* occur associated in the same jaw in an American specimen. He thought many of the teeth were not palatal teeth, but were inserted in or on the rami of the jaws.

2. "On an extinct Chelonian Reptile (*Notochelys costata*, Owen) from Australia." By Prof. Owen, C.B., F.R.S., F.G.S.

3. "On the Upper Beds of the Fifeshire Coal-Measures." By the late E. W. Binney, Esq., F.R.S., F.G.S., and James W. Kirkby, Esq.

Specimens were exhibited by Messrs. Davis and Kirkby in illustration of their papers.

February 8, 1882.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Ridley Henderson, Esq., 9 Bush Lane, E.C.; William John, Esq., M.R.C.S., Court House, Haverfordwest; and James Robert Millar Robertson, Esq., M.D., Clydeside House, Renfrew, Renfrewshire, Scotland, were elected Fellows, and Prof. S. Lovén, of Stockholm, a Foreign Member of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "Description of some Iguanodon Remains discovered at Brook, Isle of Wight, indicating a New Species, *Iguanodon Seelyi*." By J. W. Hulke, Esq., F.R.S.

2. "On a peculiar Bed of Angular Drift on the high Lower-Chalk Plain between Didcot and Chilton." By Prof. J. Prestwich, M.A., F.R.S., F.G.S.

Specimens were exhibited by J. W. Hulke, Esq., F.R.S., and Prof. J. Prestwich, F.R.S., in illustration of their papers.

ANNUAL GENERAL MEETING,

February 17, 1882.

Robert Etheridge, Esq., F.R.S., President, in the Chair.

Report of the Council for 1881.

In presenting their Report for the year 1881, the Council of the Geological Society regret that they cannot announce to the Fellows a continuation of the apparent improvement in the state of the Society's affairs which they had the gratification of indicating in their last year's Report. The cause of this is doubtless to be traced to the continued depression prevailing in all departments of business, leading to the election of a smaller number of new Fellows, and to non-payment of their subscriptions on the part of a larger number of Fellows than usual.

The number of new Fellows elected during the year is 51, of whom 44 paid their fees before the end of the year, making, with 9 previously elected Fellows who paid their fees in 1881, a total accession during the year of only 53 Fellows. Against this we have to set the loss by death of 29 Fellows, and by resignation of 7 Fellows, whilst 5 Fellows were removed from the list for non-payment of contributions, making a total loss of 41 Fellows. On the year, therefore, there is an increase of 12 Fellows. But of the 29 Fellows deceased, 8 were compounders and 10 non-contributing Fellows, and thus the number of contributing Fellows is actually increased by 22, being now 791.

The total number of Fellows and Foreign Members and Correspondents was 1432 at the end of the year 1880, and 1443 at the end of 1881.

During the year 1881 intelligence was received of the death of 2 Foreign Members. One of these vacancies in the list of Foreign Members was filled up during the year, and a second Foreign Member has been elected since the end of 1881. One Foreign Correspondent was also elected in the place of the one advanced to the higher rank, and there remains a single vacancy in the list of Foreign Correspondents.

The total Receipts on account of Income for the year 1881 were £2591 19*s.* 7*d.*, being £87 9*s.* 11*d.* less than the estimated Income for the year. The total Expenditure, on the other hand, including the cost of producing the Catalogue of the Society's Library,

amounted to £2863 19*s.* 3*d.*, or £52 11*s.* 3*d.* more than the Estimate for the year. This makes the excess of Expenditure over real Income amount to £271 19*s.* 8*d.*; but in accordance with the resolution announced in the Report of the Council for 1879, a sale of Stock was effected to meet the expense of the Catalogue,—£249 12*s.* 10*d.* of Consols were sold, producing £250 11*s.* 6*d.*, and thus the actual excess of Expenditure during the year is reduced to £21 8*s.* 2*d.*

Finding that there was some occasional demand for the Abstracts of the Proceedings issued after each Meeting of the Society, and that sets of the Abstracts, if furnished with a titlepage and index for each Session, might be available for exchange with Societies both at home and abroad whose publications are on too small a scale for exchange against the Quarterly Journal, the Council resolved that in future the Abstracts of Proceedings for each Session should bear a running pagination and be furnished with a titlepage and index, and that the remainder of the impressions at the close of the Session should be stitched in a wrapper for sale or exchange. The price for each Session was fixed at three shillings to the Public, and two shillings to Fellows.

In accordance with the announcement in the Council's last Report, the Catalogue of the Library was issued immediately after the last Anniversary Meeting. Notwithstanding the usefulness of the volume and the low price at which it is issued to Fellows, the Council regret to say that the number of impressions sold to the present time is much smaller than was expected.

The Council have to announce the completion of Vol. XXXVII. and the commencement of Vol. XXXVIII. of the Society's Quarterly Journal.

The Council have awarded the Wollaston Medal to Franz Ritter von Hauer, F.M.G.S., in recognition of his valuable labours in connexion with the Geology of Austro-Hungary, and especially for his services in long-continued Surveys of extensive areas and numerous descriptive Memoirs, and in the preparation of the Great Map of the Austrian Empire.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to Professor Jules Gosselet, F.C.G.S., in recognition of his geological labours, extending over upwards of 25 years, in the north of France and in Belgium, particularly in relation to the Palæozoic Rocks of the Ardennes; and his researches into the structure of the Franco-Belgian Coalfield, as explained in his various published Memoirs, especially his 'Esquisse Géologique du Nord de la France.'

The Lyell Medal, with a sum of Twenty-five Pounds from the proceeds of the Fund, has been awarded to Dr. John Lycett, in testimony of appreciation of the services rendered by him to geology by his investigations of the Jurassic Rocks, and his valuable palæontological works on the fossils of the Lower Oolites and on the British fossil *Trigoniæ*.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to G. J. Hinde, Esq., Ph.D., F.G.S., in recognition of the value of his contributions to the Palæontology of the Sponges, and to assist him in his further researches upon the same subject.

The balance of the proceeds of the Murchison Donation Fund has been awarded to Professor T. Rupert Jones, F.R.S., F.G.S., as a mark of appreciation of the value of his contributions to the Palæontology of the lower Invertebrates, and to assist him in his further investigations.

The balance of the proceeds of the Lyell Donation Fund has been awarded in equal parts to the Rev. Norman Glass, in recognition of his valuable investigations into the internal structure of the fossil Brachiopoda; and to Prof. C. Lapworth, F.G.S., in appreciation of his important contributions to the stratigraphy of the Silurian rocks, and to the knowledge of the structure and affinities of the Graptolites, and to assist them in the further prosecution of their respective studies.

And a sum of Twenty-five Pounds from the proceeds of the Barlow-Jameson Fund has been awarded to Baron Constantine von Ettingshausen, in recognition of the value of his contributions to British Fossil Botany, and to aid him in his further researches into the Plants of the Tertiary Period.

Report of the Library and Museum Committee.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library, both by donation and by purchase.

As Donations the Library has received about 84 volumes of separately published works and Survey Reports, and about 417 Pamphlets and separate impressions of Memoirs; also about 137 volumes and 140 detached parts of the publications of various Societies, and 15 volumes of independent Periodicals presented chiefly by their respective Editors, besides 13 volumes of Newspapers of various kinds. This will constitute a total addition to the Society's Library, by donation, of about 260 volumes and 417 pamphlets.

A great number of Maps, Plans, and Sections have been added to the Society's collections by presentation from various Geological Surveys, from the Ordnance Survey of Great Britain, and from the French Depôt de la Marine. They amount altogether to 581 sheets, and include 347 sheets from the Ordnance Survey, 162 from the Geological Survey of Great Britain, and smaller numbers from the Geological Surveys of Sweden, Norway, Finland, Prussia, Saxony, Belgium, and New South Wales.

The Books and Maps just referred to have been received from 138 personal Donors, the Editors or Publishers of 15 Periodicals, and 161 Societies, Surveys, or other Public Bodies, making in all 314 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 50 volumes of Books and of 63 parts (making about 12 volumes) of Periodicals, besides 39 parts of various works published serially. Fourteen Sheets of the Geological Survey Map of France, 12 sheets completing Dr. Wolff's Map of the Bohemian Coal-field, 7 sheets of a Map of the Coal-basin of Aix-la-Chapelle, and a Geological Map of Spain in one sheet have also been obtained by purchase.

The cost of Books, Periodicals, and Maps during the year 1881 was £64 7*s.* 3*d.*, and of Binding £38 17*s.* 5*d.* The total expenditure on account of the Library was thus £103 4*s.* 8*d.*

The Books in the Society's Library are generally in good condition; and in 1881 a considerable number of books of which the binding had suffered by use were rebound or repaired. The Library continues to be much used by the Fellows.

Museum.

The Collections in the Museum remain in much the same condition as at the date of the last Report of the Committee, the Foreign Collections being all available for reference.

The following Donations have been made to the Museum during the year 1881:—The type specimens of the "Tubulations sablonneuses" of the étage Bruxellien, described by H. J. Carter, Esq.; specimens of Tertiary Brachiopoda from South Australia, and of Belemnites from Central Australia, presented by Prof. R. Tate, F.G.S.; and a fine example of *Neuropteris heterophylla* from Cape Breton, presented by C. Barrington Brown, Esq., F.G.S.

The Society has also received, by bequest of the late Sir P. de Malpas Grey-Egerton, the series of Drawings of fossil fishes in his possession made from specimens in the Collection of the Earl of Enniskillen, F.R.S.

Comparative Statement of the Number of the Society at the close of the years 1880 and 1881.

	Dec. 31, 1880.		Dec. 31, 1881.
Compounders	312	......	311
Contributing Fellows	769	......	791
Non-contributing Fellows	268	......	259
	1349		1361
Honorary Members	3	......	3
Foreign Members	40	......	39
Foreign Correspondents	40	......	40
	1432		1443

General Statement explanatory of the Alterations in the Number of Fellows, Honorary Members, &c. at the close of the years 1880 *and* 1881.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1880			1349
Add Fellows elected during former year and paid in 1881			9
Add Fellows elected and paid in 1881			44
			1402
Deduct Compounders deceased		8	
Contributing Fellows deceased		11	
Non-contributing Fellows deceased		10	
Compounder resigned		1	
Contributing Fellows resigned		6	
Contributing Fellows removed		5	
		—	41
			1361
Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1880		83	
Deduct Foreign Members deceased	2		
Foreign Correspondent elected Foreign Member	1		
	—	3	
		80	
Add Foreign Member elected	1		
Foreign Correspondent elected	1		
	—	2	
		—	82
			1443

Deceased Fellows.

Compounders (8).

E. R. Alston, Esq.
J. Ashwell, Esq.
Sir A. Brady.
Sir P. de M. Grey-Egerton, Bart.
J. A. Hankey, Esq.
A. W. Morant, Esq.
S. Sharp, Esq.
Prof. J. Tennant.

Resident and other Contributing Fellows (11).

C. J. H. Allen, Esq.
Dr. J. J. Bigsby.
T. Checkley, Esq.
R. Clutterbuck, Esq.
J. S. Courtney, Esq.
Sir G. W. Denys, Bart.
J. Haines, Esq.
A. Hamilton, Esq.
R. Mallet, Esq.
H. Merryweather, Esq.
J. Taylor, Esq.

Non-contributing Fellows (10).

Major T. Austin.
E. W. Binney, Esq.
Rev. Dr. Cartmell.
G. Dixon, Esq.
Rev. T. England.
Rev. W. C. Kendall.
Charles Moore, Esq.
Joseph Parker, Esq.
Rev. W. Thornton.
E. P. Wilkins, Esq.

Foreign Members (2).

Dr. Ami Boué.
Prof. A. Delesse.

Fellows Resigned (7).

R. H. Brunton, Esq.
Rev. J. R. Burton.
R. H. Daubeny, Esq.
W. E. Jennings, Esq.
Rev. F. C. Lambert.
A. Laugel, Esq.
R. Taylor, Esq.

Fellows Removed (5).

J. Entwisle, Esq.
R. Koma, Esq.
W. H. Le Feuvre, Esq.
C. S. Mann, Esq.
Joseph Thompson, Esq.

The following Personage was elected from the List of Foreign Correspondents to fill the vacancy in the List of Foreign Members during the year 1881.

Il Commendatore Quintino Sella of Rome.

The following Personage was elected a Foreign Correspondent during the year 1881.

Professor E. D. Cope of Philadelphia.

The following Personages were elected Foreign Correspondents during the year 1880, *but the announcement of their names was accidentally omitted.*

Professor Luigi Bellardi of Turin.
Dr. Melchior Neumayr of Vienna.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to R. Etheridge, Esq., retiring from the office of President.

That the thanks of the Society be given to J. Evans, Esq., J. W. Hulke, Esq., and Dr. H. C. Sorby, retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. J. Gwyn Jeffreys, retiring from the office of Treasurer.

That the thanks of the Society be given to the Rev. J. F. Blake, Lieut.-Colonel H. H. Godwin-Austen, W. H. Hudleston, Esq., J. A. Phillips, Esq., and Dr. H. C. Sorby, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

J. W. Hulke, Esq., F.R.S.

VICE-PRESIDENTS.

Prof. P. M. Duncan, M.B., F.R.S.
J. Gwyn Jeffreys, LL.D., F.R.S.
Prof. N. S. Maskelyne, M.A., M.P., F.R.S.
Prof. J. Morris, M.A.

SECRETARIES.

Prof. T. G. Bonney, M.A., F.R.S.
Prof. J. W. Judd, F.R.S.

FOREIGN SECRETARY.

Warington W. Smyth, Esq., M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S.

COUNCIL.

H. Bauerman, Esq.
Prof. T. G. Bonney, M.A., F.R.S.
W. Carruthers, Esq., F.R.S.
Prof. P. M. Duncan, M.B., F.R.S.
R. Etheridge, Esq., F.R.S.
John Evans, D.C.L., LL.D., F.R.S.
J. Clarke Hawkshaw, Esq., M.A.
Rev. Edwin Hill, M.A.
G. J. Hinde, Ph.D.
J. W. Hulke, Esq., F.R.S.
J. Gwyn Jeffreys, LL.D., F.R.S.
Prof. J. W. Judd, F.R.S.
Sir J. Lubbock, Bart., D.C.L., M.P., F.R.S.
Prof. N. S. Maskelyne, M.A., M.P., F.R.S.
Prof. J. Morris, M.A.
S. R. Pattison, Esq.
Prof. J. Prestwich, M.A., F.R.S.
F. W. Rudler, Esq.
Prof. H. G. Seeley, F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
W. Topley, Esq.
Prof. T. Wiltshire, M.A., F.L.S.
Henry Woodward, LL.D., F.R.S.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1881.

Date of Election.

1827. Dr. H. von Dechen, *Bonn.*
1829. Dr. Ami Boué, *Vienna.* (*Deceased.*)
1844. William Burton Rogers, Esq., *Boston, U. S.*
1848. James Hall, Esq., *Albany, State of New York.*
1850. Professor Bernhard Studer, *Berne.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1853. Count Alexander von Keyserling, *Raykküll, Russia.*
1853. Professor L. G. de Koninck, *Liége.*
1854. M. Joachim Barrande, *Prague.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. R. Goeppert, *Breslau.*
1857. Professor H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Vienna.*
1859. Professor A. Delesse, *Paris.* (*Deceased.*)
1859. Dr. Ferdinand Roemer, *Breslau.*
1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*
1862. Professor Pierre Merian, *Basle.*
1864. M. Jules Desnoyers, *Paris.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1870. Professor Oswald Heer, *Zurich.*
1871. Dr. S. Nilsson, *Lund.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor E. Hébert, *Paris.*
1874. Professor Édouard Desor, *Neuchâtel.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.*
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Dr. F. V. Hayden, *Washington.*
1879. Major-General N. von Kokscharow, *St. Petersburg.*
1879. M. Jules Marcou, *Cambridge, U.S.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1881. Il Commendatore Quintino Sella, *Rome.*

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1881.

Date of Election.	
1863.	Dr. G. F. Jäger, *Stuttgart.*
1863.	Professor Sven Lovén, *Stockholm.*
1863.	Count A. G. Marschall, *Vienna.*
1863.	Professor G. Meneghini, *Pisa.*
1863.	Professor Giuseppe Ponzi, *Rome.*
1863.	Dr. F. Senft, *Eisenach.*
1864.	Dr. Charles Martins, *Montpellier.*
1866.	Professor J. P. Lesley, *Philadelphia.*
1866.	Professor Victor Raulin, *Bordeaux.*
1866.	Baron Achille de Zigno, *Padua.*
1870.	Professor Joseph Szabó, *Pesth.*
1870.	Professor Otto Torell, *Lund.*
1871.	M. Henri Coquand, *Marseilles.*
1871.	Professor Giovanni Capellini, *Bologna.*
1872.	Herr Dionys Stur, *Vienna.*
1872.	Professor J. D. Whitney, *Cambridge, U. S.*
1874.	Professor Igino Cocchi, *Florence.*
1874.	M. Gustave H. Cotteau, *Auxerre.*
1874.	Professor G. Seguenza, *Messina.*
1874.	Dr. J. S. Newberry, *New York.*
1874.	Dr. T. C. Winkler, *Haarlem.*
1875.	Professor Gustav Tschermak, *Vienna.*
1876.	Professor Jules Gosselet, *Lille.*
1876.	Professor Ludwig Rütimeyer, *Basle.*
1877.	Professor George J. Brush, *New Haven.*
1877.	Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1877.	Professor E. Renevier, *Lausanne.*
1877.	Count Gaston de Saporta, *Aix-en-Provence.*
1879.	Professor Pierre J. van Beneden, For. Mem. R.S., *Louvain.*
1879.	M. Édouard Dupont, *Brussels.*
1879.	Professor Guglielmo Guiscardi, *Naples.*
1879.	Professor Franz Ritter von Kobell, *Munich.*
1879.	Professor Gerhard vom Rath, *Bonn.*
1879.	Dr. Émile Sauvage, *Paris.*
1880.	Professor Luigi Bellardi, *Turin.*
1880.	Dr. Ferdinand von Hochstetter, *Vienna.*
1880.	Professor Leo Lesquereux, *Columbus.*
1880.	Dr. Melchior Neumayr, *Vienna.*
1880.	M. Alphonse Renard, *Brussels.*
1881.	Professor E. D. Cope, *Philadelphia.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. L. Agassiz.
1837. { Capt. T. P. Cautley.
Dr. H. Falconer.
1838. Professor R. Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. Elie de Beaumont.
M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac.
M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer.
Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Sir A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey-Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON "DONATION-FUND."

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Professor Richard Owen.
1839. Professor G. C. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Mr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Mr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. Mr. W. K. Parker.
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Mr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Mr. W. J. Sollas.
1879. Mr. S. Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.

AWARDS OF THE MURCHISON MEDAL

AND OF THE

PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, BART., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science,

whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Prof. H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Mr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Rev. J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Mr. C. Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Professor A. Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal.*
1882. Professor T. Rupert Jones.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Dr. W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Mr. John Evans. *Medal.*
1880. Professor F. Quenstedt.
1881. Principal J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. John Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor C. Lapworth.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. Charles Barrois.

AWARD OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF

DR. H. C. BARLOW, F.G.S.

"The perpetual interest of which is to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1879. Purchase of Microscope.
1882. Baron C. von Ettingshausen.

VALUATION OF THE SOCIETY'S PROPERTY; 31*st December*, 1881.

PROPERTY.	£	s.	d.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xxxvii. &c.				83	8	7
Due from Stanford on account of Map				9	3	4
Due from Subscribers to Journal (considered good)				2	7	8
Balance in Bankers' hands, 31 Dec. 1881				66	3	10
Balance in Clerk's hands, 31 Dec. 1881				14	16	7
Funded Property:—						
Consols, at 99	6900	7	2	6831	7	2
Reduced 3 per Cents. at 99	1036	5	5	1025	18	2
Arrears of Admission-fees (considered good)				37	16	0
Arrears of Annual Contributions (considered good)				200	0	0
				£8271	1	4

[*N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

DEBTS.	£	s.	d.
Balance in favour of the Society	8271	1	4
	£8271	1	4

J. GWYN JEFFREYS, *Treas.*

8 *Feb.* 1882.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal ..	2	7	8			
Due for Arrears of Annual Contributions	200	0	0			
Due for Arrears of Admission-fees	37	16	0			
				240	3	8
Estimated Ordinary Income for 1882 :—						
Annual Contributions from Resident Fellows, and Non-residents of 1859 to 1861				1400	0	0
Admission-fees				296	2	0
Compositions				199	10	0
Annual Contributions in advance				21	0	0
Dividends on Consols and Reduced 3 per Cents				233	2	10
Advertisements in Quarterly Journal..................				8	0	0
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's New Zealand, and List of Fellows	20	0	0			
Sale of Quarterly Journal, including Longman's account	230	0	0			
Sale of Geological Map, including Stanford's account	25	0	0			
				275	0	0
				£2672	18	6

J. GWYN JEFFREYS, TREAS.

8 *Feb.* 1882.

the Year 1882.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes and Insurance	30	5	10			
Gas	21	0	0			
Fuel	35	0	0			
Furniture	20	0	0			
House-repairs and Maintenance	20	0	0			
Annual Cleaning	20	0	0			
Washing and sundry small Expenses	30	0	0			
Tea at Meetings	16	0	0			
				192	5	10
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	110	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	38	0	0			
Charwoman and Occasional Assistance	30	0	0			
Attendants at Meetings	8	0	0			
Accountants	10	10	0			
				851	10	0
Official Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	24	0	0			
Diagrams at Meetings	2	0	0			
Postages and other expenses	75	0	0			
				126	0	0
Library				120	0	0
Publications:						
Geological Map	2	0	0			
Quarterly Journal	1000	0	0			
,, ,, Commission, Postage, and Addressing	100	0	0			
List of Fellows	35	0	0			
Abstracts, including Postage	100	0	0			
				1237	0	0
Balance in favour of the Society				146	2	8
				£2672	18	6

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1881	96	0	6			
Balance in Clerk's hands, 1 January 1881	6	8	1			
				102	8	7
Compositions				204	15	0
Arrears of Admission-fees	56	14	0			
Admission-fees, 1881	277	4	0			
				333	18	0
Arrears of Annual Contributions				163	2	6
Annual Contributions for 1881, viz.:—						
Resident Fellows	£1357	2	6			
Non-Resident Fellows	25	4	0			
				1382	6	6
Annual Contributions in advance				22	1	0
Journal Subscriptions in advance				1	12	8
Dividends on Consols	207	13	8			
,, Reduced 3 per Cents.	30	7	6			
				238	1	2
Taylor & Francis: Advertisements in Journal, Vol. 36				8	15	0
Sale of £249 12*s.* 10*d.* Consols				250	11	6
Publications:						
Sale of Journal, Vols. 1–36	116	8	10			
,, Vol. 37 *	71	4	3			
Sale of Library Catalogue	30	5	0			
Sale of Geological Map	16	16	1			
Sale of Ormerod's Index	1	18	7			
Sale of Hochstetter's New Zealand	0	12	0			
Sale of List of Fellows	0	3	0			
				237	7	9
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 37, &c.	83	8	7			
Due from Stanford on account of Geological Map	9	3	4			
	£92	11	11			
				£2944	19	8

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) H. BAUERMAN, THOMAS WILTSHIRE, } *Auditors.*

Feb. 6, 1882.

Year ending 31 *December,* 1881.

EXPENDITURE.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	21	10	0			
Fire-insurance	12	0	0			
Gas	20	18	8			
Fuel	34	6	0			
Furniture	33	16	4			
House-repairs and Maintenance	18	17	0			
Annual Cleaning	18	19	0			
Washing and sundry small Expenses	29	10	1			
Tea at Meetings	16	0	0			
				205	17	1
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	140	0	0			
Assistant in Library and Museum	110	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	36	8	0			
Charwoman and Occasional Assistance	28	4	0			
Attendants at Meetings	8	0	0			
Accountants	8	8	0			
				826	0	0
Official Expenditure:						
Stationery	26	16	4			
Miscellaneous Printing	22	15	6			
Diagrams at Meetings	1	15	6			
Postages and other Expenses	92	13	0			
				144	0	4
Library				103	4	8
Publications:						
Geological Map	38	1	9			
Journal, Vols. 1–36	10	4	9			
,, Vol. 37 ....£1040 12 3						
,, ,, Commission, Postage, and Addressing. 92 10 3						
	1133	2	6			
List of Fellows	33	12	6			
Abstracts, including Postage	99	14	1			
Library Catalogue	268	10	0			
Ormerod's Index	1	11	7			
				1584	17	2
Balance in Bankers' hands, 31 Dec. 1881	66	3	10			
Balance in Clerk's hands, 31 Dec. 1881	14	16	7			
				81	0	5
				£2944	19	8

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1881	31	15	7	Award to Dr. R. H. Traquair	18	2	7
Dividends on the Fund invested in Reduced 3 per Cents.	31	15	7	Cost of striking Gold Medal awarded to Prof. P. Martin Duncan	10	10	0
				Part cost of New Dies	3	3	0
				Balance at Bankers', 31 December 1881	31	15	7
	£63	11	2		£63	11	2

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1881	19	10	10	Award to Prof. A. Geikie, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 4 per cent. Debenture Stock	39	0	10	,, Mr. F. Rutley	28	10	10
				Balance at Bankers', 31 December 1881	19	10	10
	£58	11	8		£58	11	8

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1881	51	10	6	Award to Dr. J. W. Dawson, with Medal	25	0	0
Dividends on the Fund invested in Metropolitan $3\frac{1}{2}$ per cent. Stock	68	15	0	" Mr. G. R. Vine	21	16	9
				" Dr. Anton Fritsch	21	16	9
				Balance at Bankers', 31 December 1881	51	12	0
	£120	5	6		£120	5	6

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1881	20	10	3	Purchase of lamps for the Society's Microscopes	2	6	0
Dividends on the Fund invested in Consols	14	12	7	Balance at Bankers', 31 December 1881	32	16	10
	£35	2	10		£35	2	10

"Bigsby Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1881	12	5	9	Cost of striking Gold Medal, awarded to Dr. C. Barrois	12	5	9
Dividends on the Fund invested in New 3 per Cents.	6	2	9	Balance at Bankers', 31 December 1881	6	2	9
	£18	8	6		£18	8	6

Award of the Wollaston Medal.

In presenting the Wollaston Gold Medal to Mr. H. Bauerman, F.G.S., for transmission to Dr. Franz Ritter von Hauer, F.M.G.S., Director of the Austrian Geological Survey, the President addressed him as follows:—

Mr. Bauerman,—

In handing to you the Wollaston Medal for transmission to Franz von Hauer, I trust you will inform him that the Council of the Geological Society award this, their highest prize, in recognition of his valuable labours in connexion with the Geology of Austro-Hungary, and especially for his long-continued services in the investigation of extensive areas, and his numerous descriptive memoirs produced during the preparation of the Great Map of the Austrian Empire. Von Hauer has contributed no less than 100 papers and memoirs to geological literature, 25 of which are on palæontological subjects; he has paid particular attention to the fauna of the Hallstadt and Raibl beds, and to the Cephalopoda of the Eastern, or Austrian Alps. His descriptive pamphlets relating to the General Map of Austria are models of concise description as summarizing the results of the work of the Imperial Geological Survey. These results have also formed the basis of a general manual of Austrian Geology, which is the best guide we have to some of the most interesting parts of Central and Eastern Europe. Von Hauer has been attached to the Austrian Survey ever since its commencement in 1849; he succeeded Haidinger as Director in 1866. His great work is 'Die Geologie und ihre Anwendung auf die Kenntniss der Bodenbeschaffenheit der Österr.-ungar. Monarchie,' published in 1875. I have said enough, Sir, to enable you to inform Dr. Franz Ritter von Hauer of the high appreciation the Council have of his merits, and the satisfaction they have in recognizing them by awarding to him the Wollaston Medal.

Mr. Bauerman, in reply, said that he regretted that the compulsory absence of the Foreign Secretary, Mr. Warington W. Smyth, prevented his receiving this Medal from the hands of the President. He had much pleasure, however, in undertaking the office of transmitting to Dr. Franz von Hauer this testimony of the appreciation of his valuable labours on the part of the Geological Society. He called attention especially to the Geological Survey Map of Austria, the sheets of which were on the table, and which had been produced by the labours of the Survey under the direction of Franz von Hauer. Notwithstanding the difficulty of much of the country represented and the small scale of the map, the details were admirably worked out, and the Map itself was one of the most beautiful ever produced.

Award of the Murchison Medal.

The President then presented the Murchison Medal to Professor Jules Gosselet, F.C.G.S., of the Faculty of Sciences of Lille, and addressed him as follows:—

Professor Gosselet,—

The Council of the Geological Society has selected you to receive the Murchison Medal and part of the proceeds of the Murchison Fund, in recognition of your distinguished services to Geological science. Your labours have extended over 25 years and have been devoted to the elucidation of the history and physical structure of the north of France and Belgium, in the latter country, particularly, with relation to the Palæozoic rocks of the Ardennes, culminating in your researches into the structure of the Franco-Belgian Coal-field, so amply described and worked out in your 'Esquisse Géologique du nord de la France.' For this valuable work the French Academy of Sciences in 1881 awarded to you the Bordin prize, the highest in their power to confer upon you.

I must here mention, although but briefly, the nature of your researches. Your published papers or contributions to geological science number 22; I can only enumerate two or three which prominently stand out and show your extensive labours. In 1860–61 the Geological Society of France published your "Mémoire sur les terrains Primaires de la Belgique et du nord de la France." In the publications of the Brussels Academy of Sciences for the year 1863 appeared your paper "Sur les terrains Primaires de la Belgique." In 1873, in the 'Annales des Sciences Géologiques,' vol. iv., appeared your memoir on "Le système du Poudingue de Burnot, entre Dinant et Namur," and in the 'Bulletin' of the Academy of Sciences at Brussels, yourself and M. C. Malaise published your observations "Sur le terrain Silurien de l'Ardenne." In addition to your many papers, your work above named, 'Esquisse Géologique du nord de la France,' would place you in the front rank of observers and entitle you to high consideration. The nature and value of your investigations and the tendency of your researches led the Council to believe that the Medal founded by Sir Roderick Murchison would be worthily conferred upon you.

Professor Gosselet, in reply, said:—

Monsieur le Président,—

J'ai souvent regretté de ne pas connaître la langue anglaise; mais jamais autant qu'aujourd'hui, où je me vois forcé de vous exprimer en un langage étranger ma reconnaissance pour le grand honneur que me fait le Conseil de la Société Géologique de Londres en me décernant la médaille Murchison. Vos récompenses sont les plus

flatteuses que puisse recevoir un géologue étranger, parce qu'elles sont exemptes de toute idée d'école et de toute considération personnelle. Je suis particulièrement honoré que vous m'ayez jugé digne d'associer mon nom à celui de Murchison, du grand géologue qui a été un des fondateurs de la géologie des roches paléozoïques. Depuis mes premiers travaux géologiques, j'ai conçu une grande estime pour cet illustre savant, et dans bien des circonstances j'ai défendu sa classification des formations Siluriennes et Dévoniennes. Permettez moi d'associer à mes remercîments la Société Géologique du Nord. En décernant l'année passée une médaille à M. Barrois et en m'en décernant une cette année, vous nous avez donné une haute marque de sympathie. Nous nous efforcerons de nous en montrer dignes.

Award of the Lyell Medal.

The President next handed the Lyell Medal to Prof. J. W. Judd, F.R.S., Sec.G.S., for transmission to Dr. John Lycett, of Scarborough, and addressed him as follows:—

Professor Judd,—

The Council have awarded the Lyell Medal and part of the proceeds of the Lyell Fund to Dr. John Lycett, in recognition of his patient and long-continued researches on Jurassic palæontology, especially those devoted to the critical history and description of the Great-Oolite Mollusca of Minchinhampton, published in the Palæontographical Society's volumes for the years 1850–55, in conjunction with Professor Morris; also for his supplementary monograph in the same publication, "On the Mollusca of the Stonesfield Slate, Great Oolite, Forest Marble, and Cornbrash." Besides these, Dr. Lycett has written (1871–79) a complete and important monograph of the British Trigoniæ for the same Society, in which he describes no less than 109 species; this splendid contribution to the history of a single genus of Mollusca is probably unsurpassed in any language; and when we know that the authors of all the memoirs published by the Palæontographical Society give their time and knowledge without remuneration, we may well reward, as best we can, work done so well and so unselfishly contributed.

Dr. Lycett has contributed seventeen papers to the 'Annals and Magazine of Natural History,' and fourteen to the 'Transactions of the Cotteswold Club,' and has published a Handbook to the Geology and Palæontology of the Cotteswold Hills.

You will convey this Medal and award to Dr. Lycett, and assure him that, although he is not a Fellow of this Society, we are nevertheless not unmindful of the great service he has rendered to Jurassic palæontology.

Prof. Judd, in reply, apologized in the name of Dr. Lycett for his

absence on this occasion, which he said was due to the weak state of his health. At Dr. Lycett's request he represented him at the Meeting, and he read the following letter from Dr. Lycett:—

"Scarborough, Feb. 10, 1882.

"Dear Mr. Judd,

"I desire through you to express to the President and Fellows of the Geological Society my deep sense of the honour they confer upon me in presenting me with the Lyell Medal. I also wish to express my regret that infirmities connected with advance of years quite prevent my having the pleasure of being present upon this occasion.

"Even the little which I have been enabled to effect in the cultivation of palæontological science has always been to me a never-failing source of pleasure and satisfaction, qualified, however, by a regret that my means and opportunities have been so limited in their scope, and a conviction that all I have either accomplished or attempted is altogether insignificant in comparison with the immense field of research presented by nature to the student in palæontology.

"I remain, dear Mr. Judd,
Yours truly and faithfully,
John Lycett."

"*Professor J. W. Judd, F.R.S., F.G.S.*"

Award of the Wollaston Donation Fund.

In presenting the balance of the proceeds of the Wollaston Donation Fund to Dr. George Jennings Hinde, F.G.S., the President said:—

Dr. Hinde,—

The Council of this Society has awarded to you the balance of the proceeds of the Wollaston Fund as a testimony of their recognition of the value of your researches in certain groups of the Invertebrata and upon Glacial phenomena in Canada, the latter carried on during a residence of seven years in that country, where your entire time was spent in geological research and gaining an extensive knowledge of a large area of eastern North America, extending from Nova Scotia on the east to Nebraska on the west, and from the shores of Lake Superior to the Gulf of Mexico. Your researches on the Silurian fossils of the Niagara and Guelph formations, the Glacial phenomena of the peninsula of Western Canada, and on the Glacial and Interglacial Strata of Scarboro' heights, near Toronto, are described in the Canadian Journal. Your discovery of Conodonts and the jaws of Annelids in the Ordovician strata near Toronto showed conclusively that they were as abundant in that formation, the Silurian and Devonian

strata of North America, as in the rocks of the same age in Russia, where they had been described by Pander. This discovery of Annelid jaws proved the existence of this class, previously *supposed* to have existed in the Palæozoic strata only from their tracks; it also showed their close relationship to existing errant Annelids. This was followed by your discovering similar Annelid remains in the Silurian strata of the west of England and in the Subcarboniferous rocks of Scotland. Lastly, your careful, learned, and elaborate researches upon the large collection of fossil sponges in the British Museum, at present in MS., would alone entitle you to the consideration of the Council. I therefore in their name hand you the balance of the proceeds of the Wollaston Fund, to enable you to carry on further research and to mark their high appreciation of your labours.

Dr. Hinde, in reply, said:—

Mr. President,—

I desire to express my hearty acknowledgments to the Council of the Geological Society for the honour which they have bestowed upon me, and to you, Sir, for the kind terms in which you have conveyed the award to me. I accept it with great gratification, for I regard it not only as a complimentary recognition on the part of the Council of the work which I have done, but also as a proof of their sympathetic encouragement of my future efforts.

That I should ever accomplish any thing which would lead to my receiving the Wollaston fund did not enter into my wildest dreams when I made my early attempts, some years since, in geological investigation in that grand field for practical study, the dominion of Canada. I commenced under the guidance of my esteemed friend and former teacher, Prof. Alleyne Nicholson, then of Toronto, to whom I am deeply indebted for those initiatory lessons in practical work which have since proved invaluable to me. It was not until after trying my prentice hand on various subjects that I was induced by one or two happy finds to adopt for my special study the task of searching after and elucidating the fossils of the lower forms of animal life which, either in themselves or in their component parts, are so minute as to require the microscope for their investigation. My experience in America taught me that in order to make fresh discoveries in palæontology, it was necessary to take into the field a good lens, as well as a hammer, so as to find those little fossils which, on account of their smallness, are passed over by most observers; but I did not expect that in this country, where almost every yard of ground had been subjected to scrutiny, much remained for discovery, even amongst these small objects. I am very glad to find myself disappointed in this belief; for the little which I have explored as yet in this country convinces me that in this line of research there is abundant work yet to be done; and stimulated by the mark of your encouragement which I have this

day received, it will be my earnest effort and my hope, by patient study in this promising field, to contribute still further to the extension of the boundaries of the science which it is the object of our Society to advance.

Award of the Murchison Geological Fund.

The President next handed the balance of the proceeds of the Murchison Donation Fund to Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S., for transmission to Prof. T. Rupert Jones, F.R.S., F.G.S., and addressed him as follows:—

Prof. Bonney,—

The Council of the Geological Society has no ordinary pleasure in handing to you for Prof. Rupert Jones, F.R.S., the balance of the Murchison Donation Fund in recognition of the valuable services he has rendered to special branches of geological and palæontological science. His contributions to the history and palæontology of the Lower Invertebrata, especially the Rhizopoda and Ostracoda, have won for him European and world-wide fame. Besides several important memoirs in the volumes of the Palæontographical Society, and his share in the Treatise on Foraminifera published by the Ray Society, he contributed nearly 100 papers to various magazines and societies, especially the 'Annals and Magazine of Natural History,' between the years 1859 and 1880, and, with few exceptions, all bearing upon his favourite studies. In several of his many important communications he was associated with Mr. W. K. Parker, F.R.S.; and I may here mention his joint papers, "On the Nomenclature of the Foraminifera" and "On the Rhizopodal Fauna of the Mediterranean compared with that of the Italian and some other Tertiary Deposits," all of the utmost value for the history of these minute organisms. I can only notice, from want of time, four or five papers by himself:—1. "On the oldest known Fossil (*Eozoon canadense*) of the Laurentian Rocks of Canada," &c.; 2. "On Recent and Fossil Bivalve Entomostraca"; 3. "On the Swiss Jurassic Foraminifera"; 4. "On the Entomostraca of the Carboniferous Rocks of Scotland"; 5. "On the range in time of the Foraminifera." I may refer also to his completion and editing of Lartet and Christie's 'Reliquiæ Aquitanicæ,' ranging from 1865 to 1875, to his new edition of Dixon's 'Sussex,' to his assisting in editing the 'Micrographic Dictionary,' to his editing the 'Arctic Admiralty Manual' for the Nares Expedition in 1875, to his famous Croydon lecture, and to that most useful though small book, 'Syllabus, or Heads of Lectures for the use of Lecturers or Teachers,' by himself and Prof. Morris. Other subjects have likewise received his attention, as shown by his papers on the Primeval Rivers of England, and on the Diamond Fields of South Africa, amongst many others. Fifteen

of his papers have appeared in the Quarterly Journal of our Society. For such patient, good, and long-continued work, most of it without remuneration, the Council deem him eminently worthy of the award they offer for his acceptance.

Prof. Bonney, in reply, said :—

Mr. President,—

It is with great regret that I find myself acting today as deputy for Prof. Rupert Jones, because his absence is caused, not by official duties or engagements yet more pleasant, but by rather serious illness. I am, however, glad to have the opportunity of expressing my sympathy with him under treatment which appears to me unjust, my appreciation of him as a geologist, and my esteem for him as a man, especially for the reason that he has always been so ready to place his great stores of knowledge at the service of younger students. I proceed, then, to read the reply which he has intrusted to me :—

Mr. President,— February 17, 1882.

"This unexpected honour awarded by the Council of the Geological Society to a worker among Foraminifera and Entomostraca and a teacher of geology among the rising generation, I venture to regard rather as an incentive to still more careful work and still more earnest teaching than as an honorarium for any work done or any good results yet attained.

"The endeavour to disseminate knowledge by teaching has not been without its pleasures, though the professorial pay has ceased for want of sympathy with geology in some quarters.

"The palæontological work has always carried its reward with it, both in the fulfilment of a naturalist's duty and in the frequent friendly cooperation of fellow workers.

"The foremost of these is my distinguished friend Prof. W. K. Parker, who was associated with me by the Council some twenty years ago in a high compliment similar to that for which I now give you thanks.

"Another friend and fellow-worker, Mr. Kirkby, was honoured not long since with a similar tribute to his scientific worth and industry.

"To enjoy such associations is a reward in itself.

"To know that the Society appreciates what I have done and tried to do is in itself a reward also.

"To have this encouraging mark of its favour, as instituted by one of the best of geologists, and one of the best of my old friends, is a pleasure and an honour greater than I deserve."

Award of the Lyell Donation Fund.

In presenting to Prof. Charles Lapworth, F.G.S., of the Mason College of Science, Birmingham, one moiety of the balance of the proceeds of the Lyell Donation Fund, the President addressed him as follows :—

Prof. Lapworth,—

Those who know not your valuable contributions to palæozoic geology and palæontology have much to learn: probably no other author has so ably written upon the Graptolitidæ, or has taken a more comprehensive view of the history of life and development in the lowest rocks of the British Islands and Scandinavia than yourself.

You have enriched the literature of palæozoic palæontology by fourteen or fifteen communications of the greatest value. Chief amongst them is your paper in our Journal on the Moffat series in 1878; no recent contribution to this branch of palæontology surpasses this in research. Most of your papers have been contributed to the Geological Magazine, between the years 1870–81, and to the publications of the Glasgow and Edinburgh Geological Societies, and most of them have an important bearing upon the history of the Rhabdophora, both zoologically and stratigraphically. I may mention your papers on the British Graptolites and their allies, and on an improved classification of the Rhabdophora, both in the year 1873; also, in 1876, your paper on the Scottish Monograptidæ, and your two philosophical papers on the Tripartite division of the Lower Palæozoic rocks, and on the correlation of the Lower Palæozoic rocks of Britain and Scandinavia. I believe you are now engaged in the preparation of another paper requiring considerable research; to aid you therefore in this, the Council have awarded to you part of the proceeds of the Lyell Fund.

Prof. Lapworth, in reply, said :—

Mr. President,—

I am deeply sensible of the unexpected honour conferred upon me by the Council in making this award, and I beg to offer them my sincere thanks. I am especially grateful for the generous and flattering terms in which you, Sir, have referred to my labours and for the kindly and hearty manner in which the Fellows of the Society have received the mention of my name.

My original work in geology in the past has been the delightful employment of such few hours as I have been able to snatch from the absorbing duties and avocations of a very busy life; and to me the charms of original research are so attractive that I feel pretty confident that such leisure time as I find at my disposal in the future will most certainly be devoted to the same pursuits.

Next to the pleasure of original discovery itself is the profound satisfaction that springs from the knowledge that one possesses the interest and sympathy of one's fellow scientists. And here I have always felt that I have been more than ordinarily fortunate; for the Fellows of this Society have cheered me from the first with their kindly approval and encouragement.

I look upon this award, as I did upon that which I received a few years ago, as distinct and tangible evidence of their continued interest in my work and their desire for its continuance, and I accept it in the spirit in which it is given.

I am especially gratified that the present award is associated with the illustrious name of Sir Charles Lyell. His unbiassed conscientiousness in the accumulation of his facts, his fearless and earnest search for truth, and truth alone, and his calmness and modesty in the presentation of his magnificent results, have always made him appear in my eyes to be that one of the geologists of the modern age most worthy of respect and imitation, and I feel a profound pleasure in being thus associated, however remotely, with his illustrious name.

I can only trust that in the future which is left to me that little which I shall be able to accomplish may be performed at least somewhat in his spirit, and along those lines which shall retain for me that which I regard as one of the proudest possessions of my scientific life—the sympathy and approbation of the Fellows of this Society.

The President then presented to the Rev. Norman Glass the second moiety of the Lyell Donation Fund, and addressed him as follows:—

Mr. Glass,—

The Council have awarded to you part of the proceeds of the Lyell Donation Fund in recognition of the valuable aid and services you have rendered in elucidating the history and internal structure of the British and Foreign Brachiopoda. The generous and talented assistance you have rendered to Mr. Davidson through your method of preparing for observation the interior anatomy of the Brachiopoda, for the publication of his great 'Memoir' upon the British Palæozoic Brachiopoda, may, perhaps, only be known to a few; but those few so highly appreciate your disinterested aid, and the result of your work as depicted by Mr. Davidson, in the plates of the volumes of the Palæontographical Society, that the universal praise of your patience and industry has caused the Council to deem you richly deserving the award they ask you to receive to help you on still more with your valuable work.

Mr. Glass, in reply, said:—

Mr. President,—

I need hardly say that I greatly esteem the honour which has

been conferred upon me by the Council of this Society. The sense of this honour has been increased by my being associated with those gentlemen whose services to science you have just recognized; and I am more especially gratified in receiving this honour, Sir, from your hands, remembering the kindness and encouragement which I received from yourself and from the late Dr. S. P. Woodward more than twenty years ago, when I first began to take an interest in palæontology. Of course my work has been subsidiary to that of my honoured friend Mr. Davidson, whose scientific attainments and achievements are well known and esteemed by all who are interested in the study of geology. I have often, no doubt, during the three or four years of my labours with Mr. Davidson tried his patience; but then he has also sometimes severely tried mine; for he has persistently demanded proof, and still more proof, long after I have been convinced myself of certain peculiarities of structure. Very naturally, whilst manipulating a specimen, I often arrived at assurance myself before I could make such preparations as would convince an observer who had not been using my process for himself. However, Mr. Davidson's persistent demands for proof have only added to the assured correctness of the results obtained. Mr. Davidson I have found in many respects an admirable correspondent. Some of my friends seem to cherish the preposterous idea, that if you will only allow a letter to remain quiet long enough it will answer itself. This, however, is not the principle by which Mr. Davidson acts in his correspondence; and to the hundreds of communications I have sent to him I have hardly ever failed to receive an answer by return of post. In concluding my remarks I should like to express again the esteem with which I regard the honour which the Council of the Society has been pleased to confer upon me, and the hope I have that, inspired by their kindly recognition, I may do some further service to the science which I love so well.

Award of the Barlow-Jameson Fund.

The President next presented a portion of the proceeds of the Barlow-Jameson Fund to Baron Constantin von Ettingshausen, Professor of Botany in the University of Graz, Austria, and addressed him as follows:—

Professor von Ettingshausen,—

It is with much pleasure that the Council of the Geological Society award to you the proceeds of the Barlow-Jameson Fund, in recognition of their high appreciation of your valuable contributions to Fossil Botany. Your services to this branch of science consist in the application of your knowledge of Recent Botany to the investigation of Fossil Plants, your extensive researches into the forms and venation of recent leaves, with the view of discovering characters which would assist in determining the affinities of the

constituents of the Tertiary floras, and the success which has attended your experiments in exposing the remains of plants by freezing water which has been forced, under great pressure, into the matrix. The value of your labours is shown by your numerous memoirs on Fossil Plants, Palæozoic and Mesozoic, as well as Tertiary, published during the past thirty years, during which time you have enriched the literature of this science with no less than sixty papers, published chiefly in the Transactions of the Vienna Academy. We have also to take into consideration the important work which, in association with Mr. Gardner, you have accomplished relative to our English Tertiary fossil flora contained in the clay beds of Bournemouth and the Isles of Wight and of Sheppey. This recognition of your services will show that your labours are appreciated and valued by British palæontologists, and may encourage you to the continued prosecution of the work you have undertaken, a work which your extensive acquaintance with Tertiary floras in other lands specially fits you to perform.

Prof. von Ettingshausen, in reply, said:—

Mr. President,—

I have to express my best thanks to the Geological Society for the honour conferred on me this day by the Council of the Society, and I am especially grateful to you, Sir, for the kind manner in which you have spoken of my works. If any encouragement was needed to induce me to continue the work upon which I am engaged, it would be found in the kind words which I have received from you today.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Robert Etheridge, Esq., F.R.S.

Following the course pursued by my predecessors in this Chair, I preface my Address with brief obituary notices of some of those Fellows of the Society whose death has taken place during the past year.

With deep regret I announce the death of Sir Philip de Malpas Grey Egerton, Bart., M.P., of Oulton Park, Cheshire (one of the oldest Fellows of our Society), which took place at his town residence, 28 b, Albemarle Street, on the morning of April the 6th, 1881, after only two days' illness. Sir Philip was the eldest son of the Rev. Sir Philip Grey Egerton, the ninth Baronet and Rector of Tarporley and of the higher Mediety of Malpas. Sir Philip was born on the 13th of November, 1806, and was consequently in his 75th year at the time

of his death. He was educated at Eton and at Christ Church, Oxford, taking his degree in 1828. Sir Philip was a Deputy-Lieutenant and Justice of the Peace for Cheshire, and Lieutenant-Colonel of the Cheshire Yeomanry Cavalry; he was senior elected Trustee of the British Museum, and one of the Trustees of the Royal College of Surgeons of London, member of the Senate of the University of London, and also one of the original Trustees of the British Association.

Sir Philip Egerton was a distinguished Fellow of both the Royal and Geological Societies, to both of which he contributed many valuable papers, especially the latter, mostly connected with his favourite subject, fossil ichthyology, in which branch of palæontology he stood preeminent. When at Christ Church, Oxford, he studied geology under Buckland and Conybeare, and then commenced collecting fossil fishes in conjunction with his early friend and college-companion Lord Cole, now Earl of Enniskillen. Both undertook a lengthened tour through Germany, Switzerland, and Italy for the purpose of study and collecting. The joint collecting continued until the day of his death; and for fifty-five years Sir Philip Egerton and Lord Enniskillen ceased not to possess themselves, whenever opportunity occurred, with every thing bearing upon the history of fossil ichthyology, thus amassing together two of the largest collections ever made by private individuals. The collection made by the Earl of Enniskillen, at Florence Court, has been purchased by the Trustees of the British Museum, and is now being removed to the new Natural History Museum in Cromwell Road, South Kensington. It is also decided that the equally magnificent and unique collection made by the late Sir Philip Egerton, and now at Oulton Park, shall also form part of the National collection, thus preserving and handing down to posterity the united collection of these two distinguished naturalists; and be it remembered that Sir Philip Egerton and Lord Enniskillen collected nothing but fossil fishes, devoting their energies and means only to one great end, that of forming a collection and obtaining every thing known relative to fossil ichthyology: how they have succeeded, all palæontologists both in Europe and America fully know. The ardour of the two collectors never ceased, and the collections that thus went on side by side are undoubtedly the most complete that have ever been formed by private individuals, and mutually illustrate each other. Sir Philip Egerton enriched palæontological literature by the publication of no less than seventy-three papers upon Fossil Fishes alone, six upon Reptilia, and two upon "Cave-remains." Most of Sir Philip's papers were communicated to our Society, and published in the 'Transactions' and the 'Quarterly Journal;' he also contributed to the 'Geological Magazine.' The Memoirs and Decades of the Geological Survey were continually being enriched by his descriptions; in these volumes five whole decades, descriptive of fifty species, were entirely prepared and published through the labours and learning of Sir Philip Egerton. These memoirs, and many papers contributed to the above-named Societies from the

year 1833 furnish a sufficient indication of the wide range of Sir Philip's observations; and the light thrown by him on the structure and affinities of fossil fishes and reptiles has been of the highest value, and his writings form in the aggregate a most important contribution to our knowledge of the history of organic life. Sir Philip Egerton was elected a Fellow of the Geological Society in the year 1829, the Royal Society in 1831, the Society of Antiquaries and Royal Archæological Institute of Great Britain in 1876. He was an active member of the Councils of both the Royal and Geological Societies, as well as of the Palæontographical, at all of which he was a constant attendant.

Under the presidency of the Duke of Argyll the Council of the Geological Society in 1873 awarded to Sir Philip the Wollaston Medal, its highest recognition for distinguished services in geological and palæontological science. His Grace, on presenting the medal to Sir Philip Egerton, said, "Your services have been so great and so universally recognized, that the only difficulty I now have is not in assigning grounds for the vote which I have the pleasure of announcing, but in explaining why it has been so long delayed. That delay has been occasioned solely by the fact that you have yourself been so long an honoured member of the Council whose duty it is to consider the claims of geologists for the honours of this Society; and whatever influence you have had in that body has doubtless been exerted in favour of others to the exclusion of yourself."

In 1879 the Chester Society of Natural Science presented to Sir Philip Egerton the first Kingsley Medal, in recognition of his valuable services in promoting the objects of that Society, and the interest he took in all connected with the literature and history of the county.

Sir Philip Egerton represented the City of Chester in 1830, and continuously represented the southern division of the county until 1868, when he was returned for Western Cheshire. He was for nearly half a century in the House of Commons, being the oldest member but one in that assembly.

Prof. James Tennant, born in 1808, came to London at an early age, and entered the service of Mr. Mawe, the well-known mineralogist, whose shop in the Strand was a centre of resort for men of science. Mr. Mawe's stock consisted of shells, minerals, marbles, &c., &c., many of which Mr. Mawe obtained during his frequent travels. Here Tennant gained his first acquaintance with minerals. The classes of the Mechanics' Institution which he joined, and attendance on Faraday's Lectures at the Royal Institution, improved his education and enlarged his scientific knowledge of the specimens in which Mr. Mawe dealt. At Mr. Mawe's death the management of the business devolved upon Tennant, who shortly after succeeded to it as proprietor.

Mr. Tennant derived much advantage from the friendship of Sir

Everard Home, whose knowledge of crystallography enabled him to impart much valuable information to Tennant.

Soon after the opening of King's College the Council desired a teacher in mineralogy, and applied to Faraday for his nomination of a fit person; his recommendation was in favour of Tennant, who shortly after his appointment received the title of "Professor of Mineralogy." This new position opened a wider field of usefulness and study. Soon after, Mr. Tennant was appointed Lecturer on Mineralogy and Geology at Woolwich, a position which he retained until the lectures were discontinued.

Professor Tennant was one of the first to promote the discovery of diamonds in South Africa, always believing in their occurrence and genuineness. He was an ardent advocate of technical education; and having seen the valuable application of the lathe in cutting both diamonds and other valuable stones and marbles, he induced the Turners' Company to promote the advancement of turning by offering prizes annually for specimens in all branches of the art. Great credit is due to Professor Tennant for the revival of this branch of technical education as applied to ornamental work of all kinds and materials. Prof. Tennant was one of the founders of the Geologists' Association, of which body he was formerly President. He was elected a Fellow of this Society in 1838, and was for several years a Member of the Council. Mr. Tennant also had charge of the large collection of minerals belonging to the Baroness Burdett Coutts, whose confidence he enjoyed for many years.

Mr. Tennant superintended the cutting of the Koh-i-noor diamond; he was a liberal subscriber to many projects for the spread of education, but unobtrusively so, many of his personal friends only becoming aware of the extent to which he supported such after years had passed.

The only works by Mr. Tennant were a Stratigraphical List of British Fossils, published in 1847; Catalogue of Fossils found in the British Isles, forming the private collection of the author, 1858; On Gems and Precious Stones, 1852; a Description of the Imperial State Crown, 1858; and a Descriptive Catalogue of Gems, Precious Stones, and Pearls bequeathed to the South Kensington Museum by the Rev. Chancy Hare Townshend, 1877. Prof. Tennant died on the 23rd February, 1881.

Achille Delesse, was born at Metz, and received his early education in that town. At the age of 20 he entered the Ecole Polytechnique, passing out in 1839, to enter the "Corps des Mines." In 1845 he was appointed to the Chair of Mineralogy and Geology at Besançon, and at the same time carried on the duties of Ingénieur des Mines. After five years he returned to Paris to occupy the Chair of Geology at the Sorbonne, and became Inspector of the Quarries of Paris, which appointment he held up to 1864, when he received the appointment of Professor of Agriculture at the Ecole des Mines. In 1878 Delesse was appointed Inspector-

General of Mines, and the south-eastern district of France was put under his charge. He was elected a Foreign Member of this Society in 1859.

In the Exposition Universelle de 1855 there was a remarkable collection of mineral substances used as building-materials. Delesse was Secretary to the Jury of Class XIV.; and in the following year his "Rapport sur les Matériaux de construction de l'Exposition Universelle" appeared. Of the very numerous and valuable contributions made by him to the 'Annales des Mines' during the last thirty-nine years, one of the most important is his "Revue des Progrès de Géologie," commencing with the year 1860, of which the sixteenth and last part appeared in 1880. In this work he was assisted first by M. A. Laugel, and subsequently by M. A. de Lapparent. His memoirs in the publications of the French Academy of Sciences, the Geological Society of France, and other societies are of the greatest value, combining, as they do, the most careful work of the laboratory with observations made in the field, which his numerous travels in France, Germany, Poland, England and Ireland enabled him to make. His attention was first mostly directed to mineralogy and the chemical composition of minerals. His subsequent researches on the composition, origin, and metamorphism of rocks have done much for the elucidation of those subjects.

The subterranean inundations of the northern quarter of Paris in 1856 caused him to examine into their origin, and, with the aid of MM. Beaulieu and Yvert, he produced an elaborate report upon them in 1861, which was followed in 1867 by his 'Carte hydrologique du Département de la Seine,' also by his 'Carte hydrologique de Seine-et-Marne.' In 1871 his important work 'Lithologie des Mers de France et des Mers principales du Globe' appeared.

For many years he paid special attention to economic geology, more especially as regards agriculture, as his maps and papers testify. Achille Delesse wrote no less than 120 papers. He was made a Chevalier of the Legion of Honour in 1854, and Officer in 1876; and was elected a Foreign Member of our Society in 1859.

He died on the 24th of March, 1881, having up to the very last continued to labour for the science to which he had devoted himself.

Sir ANTONIO BRADY was born at Plymouth in 1811, and was the eldest son of the late Mr. Anthony Brady, of Plymouth. He entered the Civil Service of the Navy as a junior clerk after serving in various offices; and having been promoted to head quarters in the Victualling Yard, Deptford, upwards of fifty years since, he became head of the Contract Office, and Registrar of Public Securities in 1854. He was also appointed first Superintendant of the Purchase and Contract Department. In 1870 he retired from the Service, and received the honour of knighthood.

Sir Antonio was in the Commission of the Peace for Westminster. Since his retirement from public service Sir Antonio took a leading part in the preservation of Epping Forest for the people, and was

appointed a Judge in the Verderers' Court for the Forest of Epping. He was a Member of the Ray and Palæontographical Societies, and a Fellow of the Geological Society; and it is as such, and the position he took as a geologist, that I have to speak of him.

So long ago as 1844 his attention was drawn to the great deposits of brick-earth which occupy the valley of the Roding at Ilford near his own residence; he here commenced collecting from the Thames-valley brick-earths the rich series of mammalian remains for which they are so celebrated. Some idea may be formed of the palæontological wealth of this deposit when we know that Sir Antonio Brady obtained from it in this one locality nearly 1000 specimens of mammalian remains. In this area the conjunction of a northern and southern fauna is as remarkable as it is unique. We find associated *Elephas*, *Rhinoceros*, *Felis*, *Ursus*, *Hippopotamus*, *Megaceros*, *Bison*, and *Bos*, the Musk-ox (*Ovibos moschatus*) and the Lemming. Sir Antonio Brady's valuable collection of Pleistocene mammalia is now preserved to the nation in the British Museum of Natural History, Cromwell Road, and helps to enrich the magnificent series of our national museum. In Sir Antonio Brady's Catalogue of the Pleistocene mammalia from Ilford, Essex (printed for private circulation), he pays a just tribute to the genius and ability of Mr. Wm. Davies, F.G.S., of the British Museum, through whose instruction and aid he was able to preserve the larger specimens in his collection.

Sir Antonio Brady was elected a Fellow of the Geological Society in 1862. He died December 12th, 1881.

Mr. Charles Moore was born at Ilminster, Somersetshire, in 1814, and early had his attention drawn to geological studies. His curiosity, when a schoolboy, is said to have been first roused by accidentally opening one of the numerous nodules that occur in the Upper Lias; when split open, to his surprise he found it contained a fossil fish: the keen interest thus awakened never forsook him. From that time he commenced collecting and accumulating specimens; and before he left his native town he had already formed the nucleus of the fine collection which now enriches the Bath Museum; at the same time Mr. Moore made himself thoroughly acquainted with the physical and stratigraphical geology of the district. Mr. Moore's residence in Bath commenced in connexion with the Pump-room Library; on marrying, he, with his own patrimony and that of his wife, found himself in a position to devote himself to his geological investigations and to the service of the city, in the municipal government of which he was one of the Aldermen.

Mr. Moore was the author of thirty papers or contributions to the journals of different societies: to our own he contributed six most valuable memoirs; others were communicated to the Somersetshire Archæological Society, the Geological Magazine, and the earlier Geologist. Mr. Moore's name will probably be remembered and handed down chiefly through his discovery in England of the Rhætic beds and his subsequent researches in that formation; it

was from these beds—intermediate between the Trias and Lias, and thinly developed in this country, but largely so in the Rhætian Alps—that Mr. Moore discovered the occurrence in Britain of the oldest known mammalian genus, *Microlestes* (*M. Moorei*, Owen), thirty teeth of which were obtained by him from a fissure in the Carboniferous Limestone at Holwell, near Frome. The same genus had occurred to Plieninger from the Rhætic beds of Diegerloch, Württemberg. From the same deposit Mr. Moore obtained evidence of nine genera of reptiles and fifteen genera of fish, many new to this country. Besides this, his life-long labours are to be seen in the collection at the Museum of the Bath Institution, the contents of which were obtained and arranged by him with the same knowledge and patience that had characterized his life.

Few but those who knew Mr. Charles Moore were aware of his unwearied and patient devotion to his favourite study; and he was not more ready in acquiring knowledge than in imparting it to others. He was a faithful servant to science and public duty, possessed indomitable energy, and was a perseveringly hard worker to the last, notwithstanding his long and wasting illness.

Mr. Moore was elected a Fellow of the Geological Society in 1854, and died on December 8th, 1881.

Fort-Major Thomas Austin, who had also been a Fellow of the Society since 1854, died on the 11th March, 1881, in his 87th year. In his younger days he saw some active military service on the continent, under the command of Lord Lynedoch, who had occasion to speak highly of his courage and conduct, especially in connexion with an attack upon the village of Merxem, where he is said to have saved the life of the Duke of Clarence, and where he certainly received three wounds, one of which cost him the loss of his leg, and caused him to retire from active service. He took up his abode in Bristol, where he continued to reside until the time of his death.

Thomas Austin was a man of considerable powers and attainments, and he devoted much of his attention to various departments of science, especially Natural History. In the early days of the museum at the old Philosophical Institution in Bristol, he greatly assisted the regular Curators in the arrangement of its contents; he also delivered several lectures to the Members of that Institution on different scientific subjects. His contributions to scientific periodicals included papers on British birds, and on different geological subjects, such as rock-basins, sand dunes in various localities, raised beaches, &c.; they appeared chiefly in the 'Annals of Natural History' and in the 'Bristol Naturalist.' To our own publications he contributed several papers relating to the Geology of the shores of Waterford Haven (1839 and 1841), to Earthquake Shocks experienced in England in 1852 and 1863, and to the Cystidea and Crinoidea, published in 1848. His attention had been earlier directed to the Echinodermata, and especially to the Crinoidea, upon which he published several papers in the 'Annals of Natural History,' between 1842 and 1851; and in 1844 he commenced, with

the cooperation of his son, Thomas Austin, jun., the publication of a 'Monograph on Recent and Fossil Crinoidea,' which was originally intended to extend to 20 numbers, with 40 quarto plates, but of which only 8 parts actually appeared. The last number was published in 1847. This work contains careful descriptions and good lithographed figures of a great number of species of fossil Crinoids, many of them new, belonging to the families Platycrinidæ and Pentacrinidæ. It also includes a description and plate of the recent *Pentacrinus caput-Medusæ.*

Mr. Henry Maclauchlan. The Society has lost one of its veteran Fellows in the person of Henry Maclauchlan, who was born in 1791, and died January 4th, 1881, in his 90th year. Maclauchlan was elected a Fellow in 1832; consequently he has been connected with our Society for fifty years. In the year 1830 he was employed on the Ordnance Trigonometrical Survey; and during the Survey of the Forest of Dean in 1833 he wrote a very able description of the geology of that intricate area, entitled "Notes to accompany a Geological Map of the Forest of Dean Coalfield." This communication appeared in the 'Transactions' of the Geological Society, vol. v. part 1 (2nd series), accompanied by a most valuable geological map, probably one of the best ever constructed of the Forest Maclauchlan was associated with Buckland and Conybeare, Mr. David Mushet, and Charles Bathurst, Esq., of Sydney Park.

The Old Red Sandstone and succeeding strata are carefully described in this memoir. Besides the above he contributed notes on some fossils collected by himself and Mr. H. Still, F.G.S., during the progress of the Ordnance Survey in Pembrokeshire in 1841, which were published in the 'Transactions' of the Society, vol. vi. 1842, pp. 557–560.

Mr. Maclauchlan has lived a very retired life for many years; he was a most able and efficient officer in the service to which he was attached.

Mr. Samuel Sharp, was born at Romsey, in Hampshire, on July 18th, 1814. He received his early education at a private school in Southsea; but, owing to his father's death while he was still a boy, he removed with his family to Stamford in Lincolnshire. Mr. Sharp's stepfather was the proprietor and editor of the *Stamford Mercury*, the oldest and most widely circulated newspaper in the Midland counties; and for some years Mr. Sharp assisted him in managing and editing this journal. From a very early age he had shown a taste for the study of science, astronomy and chemistry being his favourite subjects; and his attention appears to have been directed to geology by a lecture delivered at Stamford by Mr. G. F. Richardson. Subsequently he had the advantage of studying the Oolitic districts around his home with Professor Morris and other geologists, and gradually accumulated a large and valuable collection of fossils. In 1857 Mr. Sharp removed from Stamford and went to live in the neighbourhood of Northampton. There he continued to

collect largely from the Jurassic rocks; and his work was facilitated by the excavations then being carried on in all directions for the purpose of raising the valuable iron-ore of the Northampton Sand. The general results of his observations on the district in which he lived were communicated to this Society in two valuable memoirs, which are published in our Journal.

Mr. Sharp was not only distinguished as a geologist, but his knowledge of numismatics and of local antiquities was very great; and for many years before his death he was recognized as one of the best authorities upon these subjects in the district where he lived. During thirty years he succeeded in bringing together an unrivalled collection illustrating the productions of the famous Stamford Mint; his valuable memoir on these interesting coins, with its several supplements, was published by the Numismatic Society, and constitutes the best authority on the subject; indeed, as an archæologist, Mr. Sharp was widely known, and on all questions of local antiquities he was one of the best authorities in the Midland district. He laboured energetically to found a good provincial museum in the town of Northampton, and placed therein valuable contributions from his own large geological and archæological collections. Mr. Sharp was one of the most genial and hospitable of men, and was never happier than when contributing to the instruction and pleasure of others from the stores of knowledge which he had gradually acquired concerning the geology and antiquities of his adopted county. During his later years Mr. Sharp was precluded from active exertion in the field by feebleness and ill-health; but to the end he took a lively interest in the advance of our science. Mr. Sharp was a Fellow of the Geological and Numismatic Societies, as well as of the Society of Antiquaries. He died on the 28th of January, 1882, in his 68th year.

Mr. Robert Mallet, born in Dublin on June the 3rd, 1810, commenced his education at Bective-House School in Dublin, and at the age of 16, in December 1826, went to Trinity College, Dublin, where at the end of four years he took his B.A. degree. After this he spent much time in his father's works, visiting engineering establishments in England at every opportunity.

In 1832 Mr. Mallet was elected member of the Royal Irish Academy, the 'Transactions' of which he subsequently enriched by several important papers.

Robert Mallet is chiefly known to science as a civil engineer of great eminence, and also, from his geological and physical researches, as the author of most important matter upon earthquake phenomena, contributed in the form of reports to the British Association. His great Earthquake Catalogue, prepared for that body by himself and his son, was completed in 1858: it is a lasting monument of labour and research.

His first paper on earthquake phenomena appeared in the 'Philosophical Magazine' for 1846, in which he gave an account and explanation of the vertical motion believed or supposed to

accompany earthquake shocks. This was followed in 1847 by another report to the British Association on the "Facts of Earthquake Phenomena." His first paper dealing systematically with earthquakes, and in which he propounded his dynamic theory of earthquakes, reducing their observed phenomena to the known laws of wave-motion in solids and fluids, appeared in the 'Transactions of the Royal Irish Academy' in 1848.

In 1850 Mallet was engaged on the experimental determination of the limits of transit-rate of propagation of waves of impulse, similar to those of earthquakes, through solid substances. His results are recorded in the fifth volume of the Trans. of the Royal Irish Academy, and also in his Second Report on the facts of earthquakes to the British Association. The velocities of transmission were determined in wet sand, discontinuous granite, and more solid granite respectively, on Killiney Strand and Dalkey Island.

The mean velocities obtained were:—

In wet sand	824·9	ft. per second.
In discontinuous granite	1306·4	,,
In solid granite	1664·57	,,

In 1860 Mr. Mallet carried out a series of exhaustive experiments on the same subject; and in the following year (1861) he communicated to the Royal Society full detailed results of his investigations, which were conducted and carried on at Holyhead during the progress of extensive quarrying for materials for the construction of Holyhead Harbour. Enormous blasts were fired for this purpose, and the effects measured by means of specially constructed seismometers, and an arrangement of time-recorders started and stopped by electricity; the rate of wave-transmission was obtained from metamorphic quartz rock and slate.

From 1852 to 1858, in conjunction with his son, Mr. Mallet was engaged in the preparation of his great Earthquake Catalogue and Seismic Map.

In 1857 he published (in two volumes) his work on the "Great Neapolitan Earthquake" of that year, and also communicated to the British Association his Report on the Survey and Determination of the Depth of the Focus of Impulse and the Direction of Transmission of the Elastic Wave.

In 1859 he was elected Fellow of our Society; and in 1864 the honorary degree of LL.D., Trinity College, Dublin, was conferred upon him.

In 1862 Mr. Mallet published his 'First Principles of Observational Seismology,' a development or extension of the article "Earthquake Phenomena" which appeared in the Admiralty Manual of Scientific Inquiry. One of the finest contributions to the Physical Geology of Volcanoes, and their relations to Earthquakes and Mountain-structure, was read before the Royal Society in 1872, and appeared in 1873. This paper is entitled "Volcanic Energy, an attempt to develope its true origin and cosmical relations." Mr. Mallet dis-

claims originality for that part which deals with the elevation of mountain-chains by tangential or lateral pressures, these views having been enunciated by Constant Prevost forty years previously.

Mallet's theory was that the heat from which terrestrial volcanic energy is at present derived, is produced locally within the solid shell of our globe by a transformation of the mechanical work of compression, or of crushings of portions of that shell, which are themselves produced by the more rapid contraction by cooling of the hotter material of the nucleus beneath the shell. He was the first to show that there exist all the necessary conditions for the production of volcanic heat and energy by the transformation of work into heat, in the work arising chiefly from the descent of the crust of the earth as a terraqueous cooling planet, colligating or binding together the phenomena of deformation of the earth as a spheroid of mountain-elevation and surface-depression, including faults and fissures of hypogeal or deep-seated origin, and of vulcanicity, including volcanoes and earthquakes. All these he brought together into one category of origin as the results of the same cosmical mechanism, the energy of which has decayed and is decaying as the world grows older and loses heat, more and more slowly as compared with the rate at which it lost it when a molten spheroid with a thin but ever thickening crust *.

This paper has done more to illustrate the application of thermodynamics in geology, and the necessity for a thorough mechanical and physical education to complete that of a physical geologist, than any other yet published.

Robert Mallet contributed no less than eighty-one papers to various learned societies between the years 1838 and 1880; five occur in our Journal.

Mr. Robert Mallet was elected a Fellow of the Royal Society in 1854; and he received the Wollaston Medal in 1877.

Ami Boué, was born at Hamburg, March 16, 1794. He received his early education partly in his native city, and partly in Geneva and Paris. In 1814 he proceeded to Edinburgh, and entered as a student in that University, having chosen the medical profession. The Chair of Natural History and Geology was held at that time by Prof. Robert Jameson. After every lecture one hour was always devoted to a practical demonstration by the Professor on the specimens which had been treated of; and frequent excursions were made by him with his students to the most instructive localities near Edinburgh and in Fifeshire, to study the rocks *in situ.* Under him Boué became well versed in the geology and mineralogy of that date. During his residence at Edinburgh he made geological visits to various parts of Scotland and the Hebrides, the results of which he published in 1820 at Paris. In August of 1817 he received his diploma as Doctor of Medicine.

* See Palmieri, 'The Eruption of Vesuvius in 1872; with Notice and Introductory Sketch of the present State of Knowledge of Terrestrial Vulcanicity, by Robert Mallet.' 8vo. London, 1873.

From 1817 to 1835 he mostly resided at Paris, and during that time made many long excursions through France, Germany, Austria, Hungary, Italy, &c., and for a short time resided in Switzerland. When travelling in South Transylvania in 1824 he was nearly killed by his servants, they having put poison in his chocolate one morning. When he became very ill they left him at an isolated inn on the Hungarian frontier, departing with his horses, carriage, and other effects.

In 1829 he was elected a Foreign Member of this Society.

He was present at the revolution in Paris of July 1830; but on the breaking out of the cholera in 1833, he returned to Austria.

With the help of MM. Jobert and Rozet, in the years 1830–31 he published the three volumes of the 'Journal de Géologie.' In 1832 his 'Mémoires géologiques et paléontologiques' appeared; and in 1836 his 'Guide du Géologue voyageur,' in two volumes.

During the years 1836, '37, '38 he made three journeys into Turkey, publishing the results in four volumes (at Paris) in 1840; and in the same year he published his 'Esquisse géologique de la Turquie d'Europe.'

In 1841 he became a citizen of Vienna and an Austrian, and was present during the revolution in that city of March 1848.

In 1847 the Council of this Society awarded him the Wollaston Palladium Medal for the zeal, intelligence, and perseverance with which he devoted himself to geological inquiries, both in the field and in the study, during thirty years, for his valuable and original investigations in Scotland, the South of France, the mountain regions of Bavaria, Württemberg, Switzerland, Austria, Hungary, and Transylvania, and for his scientific researches in European Turkey.

Soon after Boué left Edinburgh he published his 'Essai Géologique sur l'Ecosse.' He had the merit of being one of the first to point out to continental geologists the unsoundness of the Wernerian hypothesis; he was the first to maintain that the Muschelkalk and Quadersandstein of Germany were not identical with any English formations. Boué became a Member of the Imperial Academy of Sciences in Vienna in 1849, and was one of the founders of the Geological Society of France in 1830; he was Vice-President in 1834, and in 1835 he was elected President.

Boué has written over 200 papers and works in his own and other Journals and Transactions; five of his papers were published in the Quarterly Journal of our Society. In 1856 a short abstract appeared in our Journal (p. 325) from a paper by him, "On the probable Origin of the English Channel by means of a Fissure," in which he pointed out that it was highly probable that the English Channel has not been excavated solely by water-action, but owed its origin to one of the lines of disturbance which has fissured this portion of the earth's crust; and, taking this view of the case, the fissure probably still exists, being merely filled with comparatively loose material, and would prove a serious obstacle to any attempt

to drive a submarine tunnel across the Straits of Dover, which would have to traverse it.

Among the many eminent mineralogists and geologists with whom it was his fortune to associate are the names of Haüy, De la Fosse, Gustav Rose, Naumann, Jameson, Leonard Horner, Buckland, Conybeare, De la Beche, Murchison, Lyell, Elie de Beaumont, Dufresnoy, &c.

Enough has been given to show that we have lost another of the great pioneers whose whole life was devoted to the science of geology, working out the outlines of large areas of geological formations without the aid of railway transport and sections.

Ami Boué died at Vienna on the 21st of November, 1881, in his 89th year; and we have to regret the loss of one of our oldest Foreign Members.

Mr. Edward William Binney was born at Morton in Somersetshire, in 1812.

He was articled to a Solicitor in Chesterfield, and, after spending some time in London, settled in Manchester in 1836, residing chiefly at Cheetham Hill.

Mr. Binney soon retired from legal practice, having had no special love for the law. About two years after he took up his residence in Manchester, he, with a few other scientific friends, founded the Manchester Geological Society, the beginning of which was the work of Mr. Heywood—the late Lord Francis Egerton, M.P., being the first President, and Mr. Binney one of the first secretaries.

Mr. Binney commenced the collection (afterwards known as the Museum of that Society) which was subsequently transferred to the Natural-History Museum, and thence to Owens College.

In 1857 Mr. Binney was President of the Manchester Geological Society, and again in 1865. He was also successively Secretary, Vice-President, and President of the Literary and Philosophical Society of Manchester; the last-mentioned office, which has been filled for nearly a hundred years by men of eminence, he occupied at the time of his death. His interest in this Society never flagged; and he contributed no less than sixty-one papers to their Transactions.

Mr. Binney was elected a Fellow of our Society in 1853, and of the Royal Society in 1856. As a geologist, especially of the coal counties, Mr. Binney stood preeminent; he took great delight in encouraging the study of nature among the working classes, spending much of his time with them, and also taking geological excursions with them.

His industry is evidenced by the number of his scientific papers and notes, of which nearly 100 have been published. Ten of them appear in our own Journal. To the Palæontographical Society, of which he was Vice-President, he contributed a monograph on the Structure of Fossil-plants found in the Carboniferous Strata.

Mr. Binney was seized with paralysis whilst in a small boat

leaving the Isle of Man to join the steamer, which then conveyed him to Liverpool; he was taken to his own house at Cheetham Hill, Manchester, where he lingered for some time, and died on the 19th December last.

Mr. Binney was a keen observer of external nature, and possessed powers of observation of no ordinary kind. He was well read in science, appreciating every discovery, although pretending to originality only in his own department. He was a man of the highest honour, and remarkably outspoken, his sturdiness and strength of character being rarely equalled.

Probably few men in his district or time did more to further our knowledge of the Upper Carboniferous and Permian rocks; his reports and contributions to the Royal and Geological Societies, the Manchester Geological Society, the Manchester Literary and Philosophical Society, and the Annals of Philosophy, &c., teem with valuable information.

Mr. Binney's name will ever be remembered and associated with that of Mr. James Young, whose case he greatly assisted by his geological knowledge and inquiries in the great trial concerning the Torbane-hill Coal and Oil question.

On the Analysis and Distribution of the British Jurassic Fossils.

§ 1. Introduction.

The Secondary strata of the British Islands have received much critical attention during the past twenty years, as also have both the Jurassic and Cretaceous rocks of Europe. In this country numerous monographs upon the various groups have appeared, which have exhaustively dealt with them both zoologically and stratigraphically, in the 'Journal' of our Society, the 'Geological Magazine,' the 'Journal' of the Geologists' Association, and the volumes of the Palæontographical Society. Many valuable papers also have emanated from local field-clubs and natural-history societies.

Since the year 1860 no less than 113 papers have appeared in the 'Quarterly Journal of the Geological Society' devoted to Jurassic geology and palæontology alone. The volumes of the Palæontographical Society have issued 6 complete monographs of Jurassic groups. This great work has done more to advance British palæontology and has afforded us more complete knowledge of British species than any other publication. Its long and highly-prized career has given rise to a similar Society in Switzerland *; and several valuable monographs have already appeared in its volumes. It is hoped that every support possible will be given to this first

* Mémoires de la Société Paléontologique Suisse.

attempt on the continent to describe its fauna and flora on an extensive scale.

It may appear invidious to mention, amongst the numerous and valuable communications to the 'Quarterly Journal' of our Society, any special papers on Jurassic geology that have had marked influence upon the progress of this division of geology and palæontology during the past twenty years. In doing so, however, I regard them as having influenced and furthered the progress of exact knowledge in no small degree. It is through such detailed research and minute investigation that palæontology has taken its high stand amongst the natural sciences. A critical acquaintance with species is now essential to rightly correlate both the Jurassic, Cretaceous, and Cainozoic deposits of the British islands with those of the continent; and at no time during the past twenty years has so much been expected from students of Secondary and Tertiary palæontology.

It is my intention therefore to broadly trace the history and development of Jurassic geology and palæontology during the past twenty years, and bring down to the present time the elaborate details that have accumulated. I do so upon the plan of my last year's Address, believing that in doing so I convey to the Fellows of our Society that kind of analysis which may be useful, the materials for which I have long possessed and have now worked up for my present Address.

The correlation and identification of rocks widely separated, even in the British islands, is attended with no small difficulty, unless the specific contents of the strata are clearly understood, and the more minute particulars upon which identification is based are carefully detailed. This is at once manifest in attempting to determine the history and relations of the Lias of the south coast of England at Lyme Regis with that of the Yorkshire coast, where the physical characters and aspect of the whole stratigraphical series entirely differ.

In 1860 Dr. Wright prepared an important paper upon "The subdivisions of the Inferior Oolite in the south of England compared with the equivalent beds of that formation on the Yorkshire coast" *. None but an accomplished palæontologist could have attempted this with any chance of success, the physical differences being so extreme even over so small an area. The marine beds interstratified with the largely developed Estuarine series enable us, through the three Ammonite-zones, typically developed in the south and middle of England (Cheltenham area &c.), to read correctly the more obscure and abnormal conditions of the Lower Jurassic rocks north of the Humber, which, compared amongst themselves, have little or no value in stratigraphical geology. The more correct reading of the Jurassic fragments on the western and eastern sides of Scotland, through the careful investigations of Prof. Judd, has led to their being correlated by that geologist with almost every division of the Jurassic system. Probably no work done in modern

* Quart. Journ. Geol. Soc. vol. xvi. p. 1 (1860).

times has thrown more light upon the life-history and geographical distribution and extension of the Jurassic rocks than the labours of Mr. Judd among the western isles and on the west coast of Scotland in 1872 and 1877.

§ 2. The present Aspect of Jurassic Geology.

In 1870, Part I. of a memoir appeared in the 'Quart. Journ. of the Geol. Soc.' upon "The Oolites of Northamptonshire," by Mr. S. Sharp, F.G.S. Few counties in Mid-England offer such advantages for the study of the Jurassic rocks. Hence the two parts of Mr. Sharp's memoir (really two memoirs) have added largely to the literature of geological science, standing, as the area does, midway between Oxfordshire and Yorkshire, on the line of strike of the Lower Jurassic rocks, and in the probable centre of many physical changes.

Mr. Sharp recognized five chief divisions in the Oolites of Northamptonshire, three in the Lower and two in the Upper, the whole five having a thickness of about 130 feet; the lower members embrace the "Northampton Sand" or Inferior Oolite, and together contain 81 genera and 238 species.

The several areas are carefully described. They are:—I. Kingsthorpe; II. Northampton; III. Duston; and, IV. Blisworth. Detailed sections are given of the physical features of each area. The Ironstone-beds of the Northampton Sands are doubtless upon the same horizon as the Dogger in Yorkshire, the ferruginous beds of Glaizedale, and the Ironstones of the "ridge" in Lincolnshire. Full evidence has not occurred to show that they can be identified with the Upper Liassic Sand of the Gloucestershire Cotteswolds. The Great-Oolite fauna of Kingsthorpe, Duston, and Blisworth is remarkable for its richness in bivalve Mollusca; for out of the total of 72 genera and 195 species in all classes, 40 genera and 125 species belong to that group. Only six species of Brachiopoda are known—two *Rhynchonellæ*, and four *Terebratulæ*. The Ammonitidæ are represented by two species—*A. gracilis* and a small form; and these, with a doubtful Belemnite, and three *Nautili*, or six species in all, represent the Cephalopoda. The Echinoidea possess eleven species. The six genera occurring at Kingsthorpe and Blisworth are *Acrosalenia*, *Hemicidaris*, *Clypeus*, *Echinobrissus* and *Holectypus*. Two *Pentacrini* are doubtful forms. *Hybodus*, *Lepidotus*, *Pholidophorus*, *Pycnodus* (*P. Bucklandi*), and *Strophodus magnus* and *S. subreticulatus* are all the fishes known. These 72 genera and 195 species are distributed through the three areas in the following proportions:—

Kingsthorpe	158	species,
Duston	93	,,
Blisworth	106	,,

showing that many are common to the three areas, as would be expected; this is especially the case with the Lamellibranchiata.

The 11 genera and 30 species of Gasteropoda are nearly all confined to the Kingsthorpe area; only 7 of the 30 occur at Duston or Blisworth. *Anabacia orbulites* and *Cladophyllia Babeana* are all the corals known.

Neither the fauna nor the true position of the Northampton Sand were understood until Mr. Sharp so ably worked out the Northamptonshire beds, and showed their relation to those of Oxfordshire, the age of which was a matter of much doubt stratigraphically. The fine collection made by Mr. Sharp settled that point, and led to the reconsideration and reconstruction of that part of the Geological Survey Maps bearing upon the lateral extension and vertical thickness of these beds.

The fauna of the Northampton Sands of Northamptonshire is larger than that of the Great Oolite, the genera being 81 and the species 238. Zoologically grouped, they are as follows:—

Reptilia	2	genera and	2	species.
Ammonites	1	,,	12	,,
Nautili	1	,,	4	,,
Belemnites	1	,,	6	,,
Gasteropoda	16	,,	30	,,
Dimyaria..........	24	,,	79	,,
Monomyaria	13	,,	62	,,
Brachiopoda	2	,,	14	,,
Annelida	1	,,	3	,,
Echinoidea	10	,,	12	,,
Crustacea	1	,,	1	,,
Actinozoa	6	,,	8	,,
Amorphozoa	1	,,	1	,,
Bryozoa	1	,,	1	,,
Plantæ	1	,,	3	,,
	81		238	

The Molluscan fauna prevails, showing its moderately deep-sea character. 37 genera and 141 species of the Lamellibranchiata, and 16 genera and 30 species of Gasteropoda, 12 species of Ammonites and 4 *Nautili*, with 10 genera and 12 species of Echinoidea, nearly complete the whole fauna. Mr. Sharp gives five localities for the distribution of the Northampton-sand species:—

1. Kingsthorpe.
2. Northampton.
3. Duston Old Pit.
4. Duston Ironstone Pit.
5. Blisworth and Gayton.

In 1873, and in the 'Quart. Journal of the Geol. Soc.', appeared Mr. Sharp's second paper upon the Oolites of Northamptonshire, in which he treats of the extensive group of rocks of Inferior Oolite age, termed the *Lincolnshire Limestone*, or "Great Limestone of the Inferior Oolite." Mr. Sharp established the con-

tinuity of these beds beyond Stamford; and they are now determined beyond or north of the Humber. The author also describes the interposition, detected by Prof. Judd, of the Lower and Upper Estuarine series, a matter of high moment in the history of the Northamptonshire Oolites. The Lower belongs to the Inferior Oolite, and the Upper to the Great Oolite. Near Northampton these two freshwater or Estuarine series come together. In Oxfordshire the Upper Estuarine series is traceable up to the "Stonesfield Slate;" and the great difficulty experienced in separating the two Estuarines in Oxfordshire arose from the fact that the Northampton Sand was considered equivalent to the Stonesfield Slate. We must remember that formerly few of the fossils composing the large fauna of the Northampton Sand were known; it was through the labour of Mr. Sharp, and the inferences drawn from his splendid collection, that this long-pending question was settled, and the relations of the Northampton-Sand beds, the Collyweston Slate and Stonesfield Slate, and Lincolnshire Limestone to each other were determined; and this was a great step towards the true classification of the Lower Oolites of England. Prior to this it was believed that the Great-Oolite Limestone of the tableland of the Northampton district was identical with the Limestones which occur between Kettering and Stamford, extending on through Rutland and Lincolnshire into South Yorkshire (Cave district); also that this Limestone belonged to the Great Oolite; and that the *Calcareo-arenaceous* Slate of Collyweston and Easton, which *immediately underlies* this Limestone, was the equivalent of the Stonesfield Slate of Oxfordshire. This Limestone has been distinctly shown, on stratigraphical as well as on palæontological grounds, to be of Inferior Oolite age; and the Collyweston Slates, previously classed with the Stonesfield beds, are now relegated to their true place beneath the Inferior-Oolite or Lincolnshire Limestone. Lithologically the two beds are doubtless alike; but the *dissimilar* fossil contents of the two *similar* beds remove all doubt as to age. Sections and well-sustained arguments and views by Mr. Sharp constitute the first part of his second paper. The succession established by him was as follows:—

1. Great Oolite Limestone.
2. Upper Estuarine series.
3. Lincolnshire Limestone.
4. Lower Estuarine series, } Northampton
5. Ferruginous beds, } Sand.
6. Upper Lias Clay.

Everywhere, when exposed, this is the succession. No less than twenty carefully prepared lists of fossils accompany Mr. Sharp's memoir of 1873, each illustrating detailed sections. The presence of certain fossils, and also of groups of fossils geographically distributed, enables us to correlate the Lower Oolites, under various lithological conditions, over extended areas. The fauna of the Lincolnshire

Limestone in eleven localities is expressed in the following analysis, showing the occurrences:—

Morcot	21	genera and	31	species.
Ketton	18	,,	26	,,
Denton	26	,,	47	,,
Glendon	22	,,	29	,,
Tinkler's quarry	44	,,	87	,,
Beds above slates	19	,,	22	,,
Ponton	54	,,	139	,,
Freestone bed, Simpson's quarry	13	,,	17	,,
South of the Nene	45	,,	104	,,
Barnack Rag	57	,,	138	,,
Stamford Stone	37	,,	80	,,
	356		720	

Adding the Collyweston Slates which occur immediately below the true Lincolnshire Limestones, and which contain 25 genera and 55 species, the assumed faunal occurrences—allowing for discrepancies—are 381 genera and 775 species, which have been registered chiefly through the researches of Mr. S. Sharp, then of Dallington Hall, near Northampton. To show the paucity of species in certain classes and their abundance in others, I have constructed the following Table (I.), showing their distribution over the same geographical area above-mentioned. It clearly exhibits the faunal value of the Lincolnshire Limestone; and if a similar Table could be compiled for the Jurassic rocks of the Midland counties, and compared with those of the north and south, it would probably throw much light upon the physical history of the Jurassic rocks for the north and south and middle of England.

TABLE I.—*Distribution of the Genera and Species in the Lincolnshire Limestone of Northamptonshire.* (*Chief localities.*)

CLASSES.	Morcot.	Ketton.	Beds above Slates, Colly-weston.	Denton.	Glendon.	Simpson's Quarry.	Tinkler's Quarry.	Ponton.	South of the Nene.	Barnack Rag.	Stamford Stone.	Appearances through the 11 localities.
Reptilia	...	...	...	...	...	...	1/1	...	...	...	...	1/1
Pisces	...	1/1	...	...	...	...	2/2	...	2/2	2/3	2/3	9/11
Ammonites	...	...	...	...	...	...	1/4	...	...	...	...	1/4
Nautili	...	...	...	...	...	...	1/2	...	...	...	...	1/2
Belemnites	...	1/1	...	...	...	...	...	...	...	...	1/1	2/2
Gasteropoda	2/4	1/1	3/4	7/14	2/3	4/6	4/12	20/64	13/36	17/66	5/12	78/222
Dimyaria	7/14	7/8	6/6	8/12	11/14	4/4	14/30	17/38	16/34	14/23	14/34	118/217
Monomyaria	7/8	3/9	7/9	6/10	6/8	3/4	6/16	7/19	9/23	10/23	6/16	70/145
Brachiopoda	...	1/4	...	1/3	...	1/2	2/7	2/8	2/3	2/8	2/7	13/42
Bryozoa (none)												
Annelida	...	...	1/1	1/1	1/2	...	1/1	2/4	1/1	2/4	...	9/14
Crustacea	...	...	1/1	...	...	...	...	1/1	...	1/1	...	3/3
Echinoidea	4/4	3/3	...	4/4	2/2	1/1	3/3	1/1	1/1	3/4	2/2	24/25
Crinoidea	...	...	...	...	...	...	1/1	1/1	...	1/1	...	3/3
Asteroidea	...	...	...	...	...	...	...	...	...	...	1/1	1/1
Cœlenterata	...	1/1	...	3/3	...	...	6/6	3/3	3/4	4/4	3/3	23/24
Protozoa (none)												
Plantæ	1/1	...	1/1	...	...	...	2/2	...	...	...	2/2	6/6
	21/31	18/28	19/22	30/47	22/29	13/17	44/87	54/139	47/104	56/137	38/81	362/732

The small area under consideration shows that the accumulation of the Northamptonshire and Lincolnshire Oolites took place in shallow water, and during slow elevation, probably local. Only four species of Ammonites are known, *A. Murchisonæ*, *A. subradiatus*,

A. Blagdeni, and an undescribed form from Duston. *Nautilus* is represented by two species only, *N. obesus* and *N. polygonalis*; the Crustacea by only two species; the Asteriodea only by *Astropecten cottswoldiæ*, var. *stamfordensis*. On the other hand, the Mollusca proper, in all three groups, show a large fauna; the species of Gasteropoda obtained from the Barnack Rag, number 66, and illustrate 17 genera; from the well-known cutting at Ponton, 20 genera and 64 species are recorded. The Gasteropoda through the ten localities number 75 genera and 218 species; the Lamellibranchiata Monomyaria 63 genera and 136 species; the Dimyaria 112 genera and 211 species. The Brachiopoda have little specific value; in no instance have more than 8 species occurred in one locality. The Echinoidea and the Cœlenterata (Corals) are equally balanced. The remaining classes have no value numerically. The Collyweston species and those of the Lower Estuarine beds still require critical attention, as also the conditions of their deposition. The slates of Collyweston succeed the Lower Estuarine group; the twelve or fourteen recognized beds hold well-defined species, amongst them being *Natica cincta* (*N. leckhamptonensis*), *Unicardium impressum*, *Cardium Buckmani*, the highly characteristic *Pterocera Bentleyi*, *Trigonia compta*, *Homomya unioniformis*, *Astropecten cottswoldiæ*, var. *stamfordensis*. *Pecopteris polypodioides*, with its fronds in fructification, is abundant in the uppermost beds. The fauna of this deposit differs essentially from that of the Stonesfield Slate, with which it was for years confounded. Neither the plants, the *Trigoniæ*, nor the *Pterocera* &c. are to be confounded with the slates that underlie the Great Oolite of the Cotteswold and Oxfordshire, which contain remains of marsupials in addition to a large invertebrate fauna. All the localities named in the table prepared, and many others, are detailed by Mr. Sharp in his paper. Equally important and critical work was done in 1870 throughout Northamptonshire in the Great Oolite, Upper Estuarine, and higher members of the Lower Oolite. The valuable tables of the distribution of the Great Oolite fossils on pp. 382–385 of the 'Quart. Journ. Geol. Soc.' for 1870, embracing the three chief localities within the Northamptonshire area, I have, with the addition of three other localities (Essendine, Belmesthorpe, and Stilton), readjusted into a generic and specific analysis (Table II.), which shows the number of both genera and species in each of the six localities; thus the Great Oolite of Kingsthorpe, Duston, Blisworth, Essendine, Belmesthorpe, and Stilton is summarized, the fauna of each locality being given. Their numerical values are as follows, expressed in the same formula as in the table:—Kingsthorpe $\frac{69}{158}$, Duston $\frac{40}{93}$, Blisworth $\frac{48}{111}$, Essendine $\frac{33}{75}$, Belmesthorpe $\frac{25}{41}$, and Stilton $\frac{26}{48}$.

TABLE II., *showing the Distribution of the Great-Oolite Fauna of Northamptonshire through the following six localities.*

Classes.	Kingsthorpe.	Duston.	Blisworth.	Essendine.	Belmesthorpe.	Stilton.
Plantæ	3/3	...	1/1			
Protozoa (none).						
Cœlenterata	1/1	...	1/1			
Crinoidea	1/1	...	1/2			
Echinoidea	4/9	2/5	5/10	2/4	...	3/5
Annelida	1/1	1/1	1/1	1/1	...	1/2
Crustacea	2/2	...	...	1/1	1/1	1/1
Insecta (none).						
Bryozoa (none).						
Brachiopoda	2/6	2/3	2/5	2/4	...	2/5
Monomyaria	9/21	5/8	6/15	6/17	4/5	1/1
Dimyaria	28/77	26/66	20/57	14/35	17/29	10/18
Gasteropoda	9/25	2/7	4/8	4/9	1/3	3/3
Ammonites	1/1	...	1/2	...	1/1	1/3
Nautili	1/3	1/2	1/3	1/2	1/2	
Belemnites	1/1					
Pisces	4/5	1/1	4/6	...	...	1/7
Reptilia	2/2	...	1/1	2/2	...	3/3
	69/158	40/93	48/111	33/75	25/41	26/48

I have also appended a Table (III.) showing the relation between the Great Oolite of Northamptonshire and Lincolnshire (through the Stamford beds) to the Inferior Oolite or Lincolnshire Limestone and Northampton Sands of the same age, the third column showing the number common to the two groups, which appears to be 72, or 50 per cent. of the species of the Stamford Great Oolite. It is only through the Lamellibranchs that the Northampton Sands are allied, 36 of the 45 belonging to that group.

72 Lincolnshire Limestone or Inferior Oolite species are common to the Great Oolite (47 occur in the Northampton Sands, and 43 are common to the three divisions).

TABLE III., *showing the Relation of the Great Oolite of Northamptonshire and Lincolnshire to the Lincolnshire Limestone and Northampton Sands.*

Classes.	Great Oolite. Great Oolite, Northamptonshire.	Great Oolite. Great Oolite, Stamford.	Common to Lincolnshire Limestone.	Inferior Oolite. Lincolnshire Limestone.	Inferior Oolite. Inferior-Oolite, or Northampton Sands.
Plantæ	3	2	1	1	1
Protozoa (none).					
Cœlenterata	6	...	4	4	
Crinoidea	1				
Asteroidea	...	1	...	...	1
Echinoidea	12	8	1	1	1
Annelida	3	2	2	2	2
Crustacea	1	2			
Insecta (none).					
Bryozoa	1	1			
Brachiopoda	9	7			
Monomyaria	30	25	17	17	14
Dimyaria	87	68	29	29	22
Gasteropoda	29	15	10	10	4
Ammonites	3	4			
Nautili	3	3	...	...	1
Belemnites	2	2	1	1	1
Pisces	5	6	5	5	
Reptilia	4	4	2	2	
Mammalia (none).					
	199	150	72	72	47

In January 1873 Prof. Judd communicated to the Society his first paper "On the Secondary Rocks of Scotland."

The author, in his introduction, commenced with a description of the general characters of the Jurassic strata of Scotland, followed by that of the Cretaceous series, and finally of the Triassic. The object of Mr. Judd's memoir was to give the results of a careful study of the small patches of Secondary rocks which occur in Scotland, and to show how far the history of the Mesozoic period within that area can be reconstructed from them. The author divides the subject into three sections:—1. The Secondary Strata of the Eastern

Coast of Scotland. 2. The Secondary Strata of the Western Coast and Islands of Scotland. 3. A general Comparison of the Scottish Mesozoic Strata with their Equivalents in England and on the Continent. Nothing perhaps can be more strikingly different than the condition of the Jurassic deposits in Scotland and in the typical districts in the south and middle of England. In the south the entire series of the Jurassic rocks, from the lowest Lias to the top of the Upper Oolite, contains strata which have been deposited under various conditions, yet of undoubted marine origin—depth of water, distance from shore, and nature of sediment being all elements indicated by their present physical aspects. In England, estuarine conditions seem first to have commenced in the Rhætic at the close of the deposition of the Triassic rocks. In the midland district the Jurassic series, especially amidst its lower members, exhibits many intercalated beds possessing undoubted estuarine characters, and although insignificant in known *extent*, they are any thing but that when we investigate the causes which produced them.

In Yorkshire, during the whole of the Lower-Oolitic period, from the top of the Upper Lias, or from the Dogger to the Cornbrash inclusive, estuarine conditions prevailed over a very large area, much of which is now under the water of the German Ocean. These estuarine strata, which are nearly 1000 feet in thickness, are composed of sandstones, shales, ironstones, and thin seams of coal. The Millepore limestones and the "grey or Scarborough limestone" intercalated amidst the estuarine series are both subordinate in character and insignificant in extent as compared with the great arenaceous and shaly deposits among which they appear almost accidentally to occur, or with the marine series of the south of England.

Prof. Judd shows that as we go further north into Scotland this gradual change of conditions is carried still further. He shows conclusively that from the base of the Lower Lias, up to and including the Upper Oolite, there are a number of series of beds exhibiting estuarine characters. Mr. Judd recognizes two types of petrological character, the *argillaceous* and *arenaceous* types. The alternating groups of marine strata yield remarkable and well-preserved faunas, through which we are enabled to fix with great precision the limits of the age of these estuarine deposits.

The arenaceous type of the estuarine series is characterized by beds of sandstone and shale &c., showing every evidence of deposition under shallow-water conditions; they strikingly resemble the arenaceous series of the Lower Oolite of the Yorkshire coast.

The argillaceous type is characterized by finely laminated clays of various colours. These clays are crowded with shells of *Cyrena*, *Unio*, *Paludina*, and dwarfed *Ostreæ*, &c., with valves of *Cyprides* and *Estheriæ*; and they contain bone-beds composed of the bones of fish and reptiles, plant-remains, and interstratified lignite or coal, in places several feet thick. The conditions that prevailed at the Jurassic epoch in this area singularly confirm the conclusions of Mr. Godwin-Austen as to the existence of extended land during this long period in the North-European area.

Part 2 of Prof. Judd's first paper is devoted to the physical relations of the Secondary rocks of the east coast of Scotland. Examination of these patches of Secondary strata clearly shows that they form the last remaining vestiges of extensive formations which originally covered considerable areas, but which have subsequently been removed by denudation. Prof. Judd gives a list, at p. 113, of eight localities at present known on the east coast of Scotland where patches of Secondary strata occur. These are:—1. *Caithness*, 2. *Sutherland*; 3. *Strata between Helmsdale and Allt-chollie*; 4. *Kintradwell*; 5. *Ross*; 6. *Cadh'-an-Righ*; 7. *Cromartyshire*; and 8. *Elginshire*.

The relations of the patches of Secondary strata in the east of Scotland to the great masses of Palæozoic age are as follows:—

The Jurassic beds were deposited in a basin formed of the Old Red Sandstone rocks.

1. "The Secondary rocks lie indifferently against all the members of the Lower Palæozoic series, from the Lower Silurian and associated granites up to the Upper Old Red Sandstone."

2. "There are no indications whatever, in this series of Secondary strata, that as we approach the Palæozoic rocks we are coming to an old shore-line."

3. "The evidence of disturbance aud dislocation in the Secondary strata increases as we approach the Palæozoic rocks . . . . they are often found in a completely crumpled and crushed condition at the points of contact."

That Secondary strata to the thickness of from 2000 to 3000 feet once existed over large areas, and that they have been removed with the exception of a few patches by denudation, is now a confirmed fact. After describing the Triassic and its *Stagonolepis* and *Telerpeton* sandstones, Mr. Judd enters upon the conditions of the Lower Jurassic deposits, commencing with the Rhætic. The well-known Linksfield sandstones, which are highly fossiliferous, are still doubtfully referred stratigraphically. The fauna is that of the Upper Trias or transition series into the Lower Lias; 22 genera and 28 species are recorded by Mr. Judd.

The Lower Lias.—The coast at Dunrobin exhibits Rhætic beds passing into estuarine strata, which Mr. Judd estimated at between 400 and 500 feet in thickness, and considered to be of Lower-Middle-Lias age. A very interesting section is given (*loc. cit.* p. 143) of the series from the "Reptiliferous" (*Stagonolepis*) sandstone upwards; on p. 150 Mr. Judd gives in tabular form the nature, order of succession, and palæontological features of these Liassic strata. The fauna is that of the Lower Lias of the south and midland areas in England. Thirty-two species are named from these Dunrobin beds. The majority of the species occur in bed No. 7 in the section; numerically they are as follows:—

Belemnites	1 genus	and	1	species.
Ammonites	1	,,	4	,,
Dimyaria	9	,,	12	,,
Monomyaria	5	,,	12	,,
Brachiopoda	1	,,	2	,,
Plantæ	1	,,	1	,,
	18		32	

There can be little doubt that the fossils of the Dunrobin reefs belong to the Lower Lias, and to that portion which Quenstedt places under his division β. The absence of Echinodermata and of many forms of Mollusca occurring in the Suabian and some English beds would tend to show that the beds were probably deposited under less favourable conditions.

This may have been due to a shallower and turbulent sea, and possibly also to a colder climate. "Nevertheless," Mr. Judd suggests, "in spite of these minor peculiarities, no one acquainted with the association of Jurassic species in England, Northern France, and Western Germany can hesitate to regard these beds in the north of Scotland . . . . as included within the same ancient province of marine life" (*loc. cit.* p. 152). Mr. Judd has also found numerous fragments of shelly limestone belonging to beds that compose the upper part of the Lower Lias. These transported fragments indicate that in the east of Scotland there existed beds of limestone of Liassic age thicker than those in the patch which has escaped destruction at Dunrobin.

The clays of the Middle Lias of Dunrobin reefs have yielded 33 species:—

Belemnites	1 genus	and	2	species.
Ammonites	1	,,	4	,,
Gasteropoda	2	,,	2	,,
Dimyaria	9	,,	11	,,
Monomyaria	6	,,	11	,,
Brachiopoda	2	,,	2	,,
Crinoidea	1	,,	1	,,
	22		33	

During the periods represented by portions of the Middle Lias and the Middle Oolite more uniform and comparatively deep-water marine conditions prevailed in Scotland.

At Loch Spynie and Lhanbryd, from masses of micaceous calcareous sandstone contained in the Boulder-clay, no less than 35 genera and 60 species were collected by Mr. Judd. He believes that these fragments with Jurassic fossils, which are so abundant in the Elginshire drifts, are not far distant from the parent rocks; they probably underlie the vast masses of Boulder-clay which mask the country (*loc. cit.* p. 156).

The Lower Oolite.—In Sutherlandshire thick masses of sandstones, shales, and coals exhibit full evidence of deposition under

estuarine conditions. The author, on p. 160, gives five comparative vertical sections of the coal-bearing strata in Sutherland and Ross, viz. at Doll, Fascally, Inverbrora, Strathsteven, and Cadh'-an-Righ. Commencing at the top of each section, the well-known "Roof-bed," which is the lowest bed of the Middle Oolite, is marine in origin and of Callovian age. Twenty-four species of bivalves, all probably characterizing the Inferior Oolite, are recorded by Mr. Judd. There are 13 genera and 16 species of Dimyaria, 6 genera and 6 species of Monomyaria, and 2 species of Brachiopoda, with some plant-remains. With the exception of plant-remains, nothing but bivalves are given here.

The Middle Oolite is fully represented in Sutherland by alternating marine and estuarine strata, representing the zone of *Ammonites calloviensis.* The lowest stratum is the "Roof-bed" of the main coal-seam *. No less than 60 species occur in this "Roof-bed." *Calloviensis*-zone:—

Belemites	1	genus and	2	species.
Ammonites	1	,,	4	,,
Gasteropoda	4	,,	4	,,
Dimyaria	18	,,	33	
Monomyaria......	7	,,	15	
Saurian tooth	1	,,	1	,,
Wood-remains	1	,,	1	,,
	33		60	

The "roof-bed" above the Brora coal-series is crowded with *Ammonites Jason*; and, except in the somewhat more sandy character of the beds, this Middle Oolite is scarcely distinguishable in any way from its equivalent in many parts of Suabia, France, and England.

Prof. Judd gives the names of 30 species from the argillaceous series above the Brora coal-series and the "*Am. ornatus*" clays:—

Belemnites	1	genus and	2	species.
Ammonites	1	,,	12	,,
Gasteropoda	3	,,	4	,,
Dimyaria	8	,,	8	,,
Monomyaria......	4	,,	4	,,
Wood				
	17		30	

We are struck here with the preponderance of species of Ammonites, which also occurs in the Yorkshire Kellaways rock, and

* I have collected from this bed underground in the Brora pit *Pholadomya Murchisonii, Anatina undulata, Goniomya, Isocardia tenera, Modiola cuneata, Pinna, Pteroperna, Pecten lens,* and *Gryphæa dilatata.*—R. E.

almost in the same number and species. The zone of *Ammonites perarmatus* and the Oolitic series are succeeded by the sandstones of the group *Cordati*, also associated with species of the *Armati* and *Planulati*; they are succeeded by the Clynlish and Hare-Hill or Braamberry-Hill white sandstones, which have yielded a large fauna (40 genera and 67 species):—

Belemnites	1 genus	and	2	species.
Ammonites	1	,,	11	,,
Gasteropoda	5	,,	5	,,
Dimyaria........	15	,,	19	,,
Monomyaria	12	,,	23	,,
Brachiopoda	2	,,	2	,,
Echinoidea	1	,,	1	,,
Plantæ..........	3	,,	4	,,
	40		67	

The remarkable group of Cycads, *Bucklandia Milleriana, Yatesia Joassiana* and *Y. crassa* mark an epoch in the flora of the Middle Oolites. The Ammonites all differ from those of the zone of *Ornati*; but numerically they are much the same.

Coralline Oolite.—On the left bank of the Brora and at Ardassie Point a characteristic fauna occurs, the *Cordati* amongst the Ammonites being the only group present. At both points the fossils are the same; 24 genera and 42 species occur in the argillaceous limestones of the Brora, and 26 genera and 42 species at Ardassie.

The faunas of the various limestones and clays leave no doubt as to their age or true geological horizon; it is unmistakably that of the Coralline Oolite of England. Mr. Judd estimates that the Middle-Oolite series of Sutherland attains a thickness of nearly 900 feet, about one half of which is made up of marine, and the other half of estuarine strata (*loc. cit.* p. 176).

The Upper Oolite.—This is for the first time recognized in the northern part of the British Islands, and represented by a great series of shales, sandstones, and grits, nearly 1000 feet thick. The fauna belongs unquestionably to the Upper Oolite. The marine sandstones of "Alt-na-Cuil" have yielded 17 genera and 28 species. The Upper Oolite series has yielded a large and beautiful flora of Cycadeæ, Coniferæ, Filiceæ, &c.*

Mr. Judd's list of fossils from the limestones, grits, and shales of the Upper Oolite of Sutherland represents a copious and important fauna, numbering 36 genera and 61 species:—

* First noticed by Hugh Miller, 'Testimony of the Rocks' (*vide* the last two chapters).

Reptilia	1	genus and	1	species.
Pisces	2	,,	2	,,
Belemnites	1	,,	3	,,
Ammonites	1	,,	11	,,
Gasteropoda	8	,,	8	,,
Dimyaria	5	,,	6	,,
Monomyaria	7	,,	15	,,
Brachiopoda	3	,,	5	,,
Annelida	1	,,	2	,,
Echinoidea	2	,,	3	,,
Cœlenterata	2	,,	2	,,
Plantæ	3	,,	3	,,
	36		61	

These beds have hitherto been regarded as of Liassic age; the fauna, however, leaves no doubt as to the horizon to which they belong. The group *Planulati*, the Belemnites, the Brachiopoda, and the Plantæ all definitely fix the age of these calcareous and arenaceous beds.

The Eathie-Bay beds south of Cromarty are remarkable for the series of Cephalopoda; the Ammonites and Belemnites more than equal all other groups yet obtained, the former yielding 12 species, the latter 3; only one species each of Gasteropoda and Dimyaria have occurred, and 5 species of Monomyaria. Leaves and cones of Coniferæ, leaves, buds, and stems of Cycadeæ, and fronds of ferns occur. The Ammonites indicate that the fauna may be assigned to the age of the Kimmeridge Clay and to the zones of *Ammonites mutabilis* and *A. alternans* of Dr. Waagen. These strata, so far as we know, form the highest beds of the Secondary rocks exposed "*in situ* on the east coast of Scotland" (Judd, *loc. cit.* pp. 181, 184).

Prof. Judd's Table No. I., facing p. 194, is a masterpiece of compilation and composition. The centre column, devoted to the characteristic fossils, is of the highest value to the stratigraphical geologist; it gives a most complete history of the successive horizons from the Lower Lias to the lower part of the Kimmeridge Clay. In Sutherland alone we have good evidence of 13 horizons. Mr. Judd's Table epitomizes the contents of his paper so as to leave little wanting to elucidate the history of the Lower, Middle, and Upper Oolites of the east of Scotland. To analyze this Table would be almost impossible; but, to a certain extent, I have done it in giving a summary of the author's discoveries in Sutherland.

His table No. II. gives a comparative view of all the Secondary rocks of the east of Scotland, from the Trias to the Upper Greensand; the division of the groups of Ammonites; nature of deposit, whether marine or estuarine; thickness; and where certain strata are seen *in situ* in other counties.

In January 1878 Prof. Judd communicated his second paper on the Secondary rocks of Scotland (the Strata of the Western Coast and Islands). The intermediate paper of 1874 had reference chiefly to

the volcanic phenomena of the Highlands associated with the Tertiary and newer Palæozoic periods.

In the Hebrides and adjoining portions of the Western Highlands there occur more or less isolated patches of limestone, sandstone, and shale, which are in places fossiliferous. These isolated patches of Secondary strata are widely scattered over an area measuring 120 miles in length from north to south, and 50 miles in breadth from east to west. Again, as Mr. Judd points out, "there are various deposits of Mesozoic age in the counties of Sutherland, Ross, and Elgin, the nearest of which lies 100 miles to the north-east of the most northern patch of Secondary strata in the Western Isles; and these fragments of Secondary strata in the Eastern Highlands have . . . . escaped destruction by denudation only in consequence of being let down many hundreds, or even thousands, of feet below their original positions, and thus coming to be preserved in the very heart of the harder Palæozoic masses."

Mr. Judd believes, and with every reason, that "the whole of the north and north-west portions of the British archipelago, now sculptured by denudation into a rugged mountain-land, were, like the south and south-eastern parts of England, to a great extent, if not completely, covered by sedimentary deposits, ranging in age from the Carboniferous to the Cretaceous inclusive; and that, as a consequence, we must refer the production of the striking and very characteristic features of those Highland districts to the *last great epoch* of the earth's history—the Tertiary—*and very largely*, indeed, to the latest portion of that epoch, namely the Pliocene" (*loc. cit.* p. 669). Mr. Judd also believes, from good evidence and inductive reasoning, that during all the geological periods, from the Carboniferous to the Cretaceous inclusive, a very large part of the Highland districts was submerged and formed areas of deposition, and also that some portions of that Highland region did, during those long periods, exist more or less continuously as islands. Again, so uniformly similar was the succession of life-forms during the Mesozoic deposits, as exposed in Central Germany, Northern France, England, Scotland, and Ireland respectively, that it seems impossible to doubt that the Jurassic and Cretaceous deposits of all those areas were accumulated in the same sea—one in which the diffusion of forms of life was not impeded by the existence of any great continuous barrier of land (Judd, *loc. cit.* p. 670).

Infra Lias.—The zone of *Avicula contorta* does not exist on the west coast of Scotland. The series that occurs next in succession, the Infra Lias proper, as exposed at Applecross, Mr. Judd believes has no equal in the British Islands. It is 120 feet thick: its fossils include *Ostrea irregularis*, *O. arietis*, *Lima Hermanni*, *Phasianella*, *Thecosmilia Martini*, &c.

Lower Lias.—The Lower Lias is largely developed in the Hebrides and adjacent mainland of Scotland; it is in places richly fossiliferous, and in some sections 400 feet in thickness. These beds strikingly resemble, both in their lithological and palæontological characters, their equivalents in England. The great floors of lime-

stone and shale, being crowded with *Gryphæa arcuata* (*incurva*) and abounding in *Lima gigantea*, with *Ammonites of the group* of the *Arietes*, cannot fail to show that they are the well-known *Lima* or *Bucklandi* beds of the south (*loc. cit.* p. 701).

Besides the above-named fossils, *Am. Bucklandi*, *A. Conybeari*, *A. Kridion*, *Nautilus striatus*, *Pinna Hartmanni*, *Lima pectinoides*, *Spirifera Walcotti*, &c. tend to correlate these beds with the well-known deposits of England, Burgundy, and Württemberg. At Applecross Mr. Judd obtained, besides the above, *Modiola psilonoti*, *Avicula sinemuriensis*, *Pecten textorius*, *Unicardium cardioides*, *Cardinia Listeri*, *C. crassiuscula*, *Astarte dentilabrum*, and *Pentacrini*. All the same species occur on the shore at Broadford Bay, Skye. A little higher in the section occurs *Am. semicostatus* and *A. Sauzeanus*, the more typical *Bucklandi* forms having disappeared. Mr. Judd says that nowhere in the Western Highlands can the Lower Lias be studied to greater advantage than on the shores of Loch Aline, on the eastern side of the Sound of Mull; 18 genera and 30 species have been found there. Numerically they are as follows:—

Ichthyosaurus vertebræ.				
Ammonites	1	genus and	7	species.
Nautilus	1	,,	1	,,
Gasteropoda	1	,,	1	,,
Dimyaria	4	,,	5	,,
Monomyaria	6	,,	11	,,
Annelida	1	,,	1	,,
Echinoidea	1	,,	1	,,
Crinoidea	1	,,	2	,,
Plantæ	1	,,	1	,,
	18		30	

It will be perceived that the Ammonites and Bivalves constitute the chief mass of the species. Only one Gasteropod, and that a doubtful *Phasianella*, occurs here.

The Middle Lias.—The two well-marked members of this division are the lowest or "*Pabba series*" and the upper or "*Scalpa series.*" The former consists of sandy shales; the latter of a great thickness of calcareous sandstones. Each of these divisions contains a distinctive fauna; the Pabba Shales represent Quenstedt's Lias γ (the zones of *Am. Jamesoni*, *A. Ibex*, and *A. Davœi*, of Oppel); while the Scalpa series is equivalent to Lias δ, or the zones of *Am. margaritatus* and *A. spinatus* of Quenstedt (*loc. cit.* p. 710). The Middle Lias on the east side of the island of Raasay is grandly developed, and 500 feet in thickness. Mr. Judd names the following fossils as being most common—*Belemnites breviformis*, *Am. margaritatus*, *A. Engelhardti*, *Pecten æquivalvis*, *P. sublævis*, *P. liasinus*, *Gryphæa cymbium*, *G. gigantea*, *Rhynchonella tetrahedra*, *R. acuta*, and *Spirifera Walcotti*. It will be seen that these, amongst others, are the well-known species of the Middle Lias of England.

From Scalpa Mr. Judd has recorded 25 species, representing 12 genera. In Tobermory the "Pabba Shales" have yielded to Mr. Hugh Miller, F.G.S., of the Geological Survey, 18 genera and 31 species, a fauna differing from that named above, namely:—

Belemnites	1	genus and	2	species.
Ammonites	1	,,	6	,,
Gasteropoda......	2	,,	2	,,
Dimyaria	8	,,	11	,,
Monomyaria	6	,,	10	,,
	18		31	

The Upper Lias.—The parallelism of the Upper Lias of Scotland with that of England is striking and absolute. In the upper part we find *Am. communis* &c. associated with *Posidonomya Bronni* and Belemnites; at the base abundance of *Am. serpentinus*, *A. radians*, *A. elegans*, and others belonging to the group *Falciferi* (loc. cit. pp. 717, 718).

Looking at the uniform extension of the Lias group through England from Lyme Regis to Redcar continuously as the western edge of the strike, so left by denudation, and seeing that only at one place to the west (Wem, in Shropshire), besides probably a patch in Cumberland and the Lower Lias of the Antrim coast, we must be astonished to see such a development of the English southern and north-eastern beds so far to the N.W.; and, but for the exposures above named, no evidence would have been afforded us of any extension to the N.W. The researches of Mr. Judd have, however, thrown new light upon the geographical extension and distribution in time of the Lower Jurassic rocks, leaving us to restore the lost area and still older series now below the North Atlantic and to the west of the Hebrides. The "patches" left of these Mesozoic rocks so rich in organic remains on and around the islands that fringe the Highland coast, testify to the grandeur and extent of the original deposit; probably nowhere in Europe were the Secondary rocks more completely developed.

The Lower Oolite.—Mr. Judd, in discussing these members of the Jurassic series, states that they must have had a very extended geographical distribution and been of considerable thickness; they have been detected at various points from the Shiant Isles in the north to Ardnamurchan in the south, forming, indeed, what would be the eastern edge of the northern Jurassic basin. The Inferior Oolite in the Western Islands is probably 400 feet thick. Mr. Judd divides the series into four members:—

No. 1. Marine.
,, 2. Estuarine.
,, 3. Marine, with *Am. Blagdeni*, *A. Humphriesianus*, *A. coronatus*, and *Bel. giganteus*.
,, 4. Marine, with *Am. Murchisonæ*, *A. corrugatus*, and *A. læviusculus*.

Mr. Judd also believes that he has detected fossils indicating the presence of a representative of the Midford Sands of England.

In the isolated and distant Shiant Isles the beds containing *Ammonites Murchisonæ* and *A. corrugatus* are well shown, although the shales are metamorphosed into masses resembling Lydian stone. These Ammonites, *Belemnites giganteus*, *Rhynchonella spinosa*, and other well-known species occur further south in Ardnamurchan: to the south of this the overlap of the Upper Cretaceous rocks covers up the Jurassic series.

The Great Estuarine Series.—In Skye and Raasay certain beds which have pronounced estuarine characters succeed the Lower Oolites of the Western Isles, and are intercalated between them and the representative of the Oxford Clay. In Eigg and Muck they are thicker. As on the eastern coast of Scotland, two distinct types occur, the arenaceous and the argillo-calcareous, the former resembling the Hastings Sand, and the latter bearing a most striking analogy to the Purbeck and Punfield series of the south of England. This series is completely and carefully described by Mr. Judd (*loc. cit.* pp. 722–726).

The Oxford Clay.—This group immediately overlies the Great Estuarine series. It consists of blue clays and argillaceous limestones of marine origin. These clays contain a fauna representing the zone of *Ammonites cordatus*, or the middle part of the Oxford Clay. Edward Forbes obtained fossils from clays of the same age at Loch Staffin. Mr. Judd gives a list from the Bay of Laig, Island of Eigg, in which no fewer than 7 species out of 19 are Ammonites and 2 Belemnites, *B. sulcatus* and *B. gracilis*; so that 9 are Cephalopoda. There are also 6 genera and 7 species of Bivalves, a *Serpula*, a fish-defence, and wood—in all 19 species. Prof. Judd believes that beds of this age, although imperfectly exposed, must underlie great tracts of the Miocene basalts of the Hebrides. The Oxford Clay of Scotland and England was deposited in a sea of considerable depth; probably its beds originally extended over much of what is now the area of the British Islands. In mineral characters and life-succession it strikingly resembles the Anglo-Germanic area; and there can be no doubt that the Oxfordian sea of that life-province was of wide extent and of considerable depth, and probably not broken up into a number of isolated portions (*loc. cit.* p. 727). The remainder of Mr. Judd's able memoir is devoted to the Cretaceous system of the Western Highlands. With the Cretaceous group I have at present nothing to do, the Jurassic series alone being too extensive for one Address.

The Table facing p. 736 is an elaborate exposition of the matter contained in the paper. It ranges from the Poikilitic rocks to the Chalk, and gives the characteristic fossils in each division of the several formations and foreign equivalents. The following is a short analysis of it:—

Formations.	Thickness.	Equivalents.
Chalk	3 divisions, in all 130 feet, upper part, =	1. The Maestricht and Meudon beds? or Eocene? 2. The zone of *Bel. mucronatus.* 3. Middle Lower Chalk.
Upper Greensand	60 ,, ,,	Cenomanian.
Middle Oxfordian	very considerable.	
	Great unconformable break.	
Great Estuarine series	3 divisions 850 feet.	Lower Oxfordian and Great Oolite.
Lower Oolites	4 ,, 385 ,,	1. Inferior Oolite, zone of *Am. Parkinsoni.* 2. Zone of *Am. Humphriesianus.* 3. Zone of *A. Murchisonæ.*
Upper Lias	1 division 100 ,,	Upper Lias Clay.
Middle Lias	3 divisions 500 ,,	1. Zone of *Am. spinatus* and *Am. margaritatus.* 2. Zone of *A. Jamesoni.* 3. Zone of *Am. armatus, A. ibex,* and *A. oxynotus.*
Lower Lias	2 ,, 400 ,,	1. Zone of *Am. semicostatus.* 2. Zone of *Am. Bucklandi.*
Infra Lias	1 division 400 ,,	Zone of *Am. angulatus* and *Am. planorbis.*
	2635 feet.	

The accompanying Table (IV.) exhibits the Ammonites that occur in the Jurassic strata of the eastern and western sides of Scotland, and in the patches left by denudation. This Table has been compiled from the various collections made by Mr. Judd and the species mentioned in his paper. The Lower Lias embraces 12 species, the Middle Lias 14, the Upper Lias 5, the Middle Oolite 27, and the Upper Ooolite 23 species—in all 81 species. Equally important and instructive would have been the tabulation of the whole fauna of these northern Jurassic rocks; but my Address will greatly exceed the limits I had intended, and tabular matter requires long explanation. I have selected the Ammonites because they are of high stratigraphical importance, and their acknowledged zonal value carries with it definite ideas for correlation. This Table is a singular and complete illustration and confirmation of the stratigraphical value of the distribution of the Ammonites in time and space, clearly showing the succession of groups of species through the long continuous deposition of the sedimentary matter composing the Jurassic rocks over the entire European area.

In addition to giving the tabular distribution of the Ammonites only in the patches left by denudation on the east and west coasts of Scotland, I have prepared a second Table (V.) for the distribution of all the known species in the same localities, arranging them stratigraphically. The numerical development and distribution of the Mollusca is a significant feature in this Table; ten of the fifteen classes are scarcely represented; but it is evident from the associated fauna that the Jurassic rocks of the Scottish area have yet to yield a rich harvest of species. The genera are not largely represented by species, clearly showing the want of systematic

research and collecting; but for the researches of Prof. Tate, Edward Forbes, Dr. Bryce, Prof. Geikie, and Prof. Judd we should have known little or nothing of the Jurassic fauna of the Western Isles or the eastern shores of Scotland*.

Probably two of the most painstaking and elaborate papers of the past twenty years have been written by W. H. Hudleston, Esq., M.A., F.G.S. The first part of the first memoir appeared in August 1874, the second in January 1876, and the third in October 1878, in the 'Proceedings of the Geologists' Association.' The title of Mr. Hudleston's memoir is "The Yorkshire Oolites;" and no prior description of the geology and palæontology of Yorkshire can compare with it for the philosophical way in which the author has treated this most difficult problem in the history of the lower Secondary rocks of Britain.

Mr. Hudleston's second memoir appeared in the 'Geological Magazine' for the months of June, July, September, November, and December 1880; it is entitled "Contributions to the Palæontology of the Yorkshire Oolites," and is a companion memoir to the one above-cited. I commend these two able productions to every student of Jurassic geology in Europe; without them our knowledge of the Oolitic rocks of Yorkshire would still be very imperfect. Louis Hunton, Phillips, Williamson, Wright, Leckenby, Lycett, Tate, and Blake have, however, enriched our knowledge of the geology of this great county; and the geological maps of the eastern division constructed by Mr. Fox Strangways, both on the 6-inch and 1-inch scale, are works of art, in the department of geological surveying, such as have seldom been attempted and rarely excelled.

Mr. Hudleston, in his first part, divides and treats his subject under three heads:—

1. The Physical Geography of the District.
2. The Region of the Lower Oolites.
3. The Lower Oolites.

This last division he treats under four heads:—

1. The Dogger.
2. The Millepore bed.
3. The Scarborough or Grey Limestone.
4. The Cornbrash.

Below the Dogger ranges the uppermost division of the Upper Lias, or the transition Jurassic sands, viz. (1) "*The Yellow sand series*," about 20 feet thick; (2) below these the well-known "Grey sands" which form so conspicuous a platform at low water; and (3) at the base the *Am.-striatulus* beds, which shade into the Grey sands above: the whole may measure about 100 feet. The Blue Hythe Point section is probably one of the grandest and most interesting in its details on the whole coast of Yorkshire; no one who has not personally examined this, both from the bays and in the cliffs, can form any idea of the history of the

* *Vide* Quart. Journ. Geol. Soc. vol. vii. p. 104, vol. xiv. p. 24, vol. xxix. pp. 97 and 339, papers by Edward Forbes, Dr. Wright, Prof. R. Tate, and Prof. Judd.

[To face p. 80.

TABLE IV.—*Species of Ammonites occurring in the Jurassic Patches on the East and West Coasts of Scotland.*

	Lower Lias.			Middle Lias.				Up. Lias.		Middle Oolite.							Upper Oolite.				
—— rupellensis													*								
—— plicatilis													*		*	*					
—— lunula													*								
—— anceps albus													*								
—— vertebralis														*	*	*					
—— Lamberti														*	*						*
—— Mariæ																					*
—— eudoxus																	*		*	*	
—— biplex																	*	*	*	*	
—— Achilles																	*		*	*	
—— triplicatus																	*		*	*	
—— mutabilis																	*		*	*	
—— ——, var.																				*	
—— alternans																		*	*	*	
—— ——, var.																				*	
—— flexuosus																		*	*	*	
—— Beaugrandi																			*	*	
—— Calisto																			*	*	
—— autissiodorensis																			*		
—— Gravesianus																				*	
—— Williamsoni																					*
—— arduennensis																					*
—— toucasianus																					*
75	4	3	7	4	1	2	3	7	5	7	4	12	4	10	4	5	5	5	3	10	12	8
	Lower Lias. 12.			Middle Lias. 14.				Up. Lias. 5.		Middle Oolite. 27.							Upper Oolite. 21.				= 79.

Note.—Localities Nos. 7, 8, 10, and 22 are West-coast patches.

TABLE IV.—*Species of Ammonites occurring in the Jurassic Patches on the East and West Coasts of Scotland.*

	Lower Lias.			Middle Lias.					Up. Lias.		Middle Oolite.							Upper Oolite.				
	Dunrobin Reefs.	Inverugie.	Loch Aline.	Dunrobin reefs.	Loch Spynie.	Lhanbryd.	Scalpa.	Pabba Shales, Tobermory.	Upper Lias.	Raasay and Skye.	Roof-bed, Brora. Kellaways Rock.	Above Brora coals. Oxf. Clay.	Cadh'-an-righ. Cor. Oolite.	Braamberry Hill. Cor. Oolite.	Left bank of Brora. Cor. Oolite.	Ardassie Point. Cor. Oolite.	Port-an-righ. Cor. Oolite.	Alt-na-Cuil. Kim. Clay?	Alt Chollie. Kim. Clay.	Kintradwell, &c. Kim. Clay.	Eathie. Kim. Clay.	Eigg. Oxford Clay.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
Ammonites caprotinus	*	*																				
—— oxynotus	*	*		*																		
—— ——, var.	*																					
—— sp.	*																					
—— Masseanus		*																				
—— brevispina				*				*														
—— ——, var.				*																		
—— Jamesoni				*	*			*		*												
—— Actæon						*																
—— sp.						*																
—— Bucklandi			*							*												
—— multicostatus			*							*												
—— Conybeari			*																			
—— Kridion			*																			
—— spinares			*																			
—— spiratissimus			*																			
—— sp.			*																			
—— spinatus							*			*												
—— margaritatus							*			*												
—— ——, var.							*															
—— raricostatus								*														
—— densinodus								*														
—— Buvignieri								*														
—— ibex								*														
—— Valdani								*														
—— radians									*													
—— falcifer									*	*												
—— comensis									*	*												
—— serpentinus									*													
—— elegans									*													
—— Gowerianus											*											
—— sublævis											*											
—— Kœnigi											*	*										
—— sp.											*											
—— ornatus												*										
—— Jason												*										
—— Gulielmi												*										
—— Comptoni												*										
—— Duncani												*										
—— Sedgvici												*										
—— Lonsdalei												*										
—— Elizabethæ												*										
—— Bakeriæ												*										
—— Reginaldi												*					*					
—— athleta												*										
—— cordatus													*	*	*	*	*					*
—— Sutherlandiæ													*	*								*
—— excavatus													*	*	*	*	*					*
—— perarmatus													*	*								
—— —— Edwardsianus														*								
—— Babeanus														*								
—— rupellensis														*								
—— plicatilis														*		*	*					
—— lunula														*								
—— anceps albus														*								
—— vertebralis															*	*	*					
—— Lamberti															*	*						*
—— Mariæ																						*
—— eudoxus																		*		*	*	
—— biplex																		*	*	*	*	
—— Achilles																		*		*	*	
—— triplicatus																		*		*	*	
—— mutabilis																		*		*	*	
—— ——, var.																					*	
—— alternans																			*	*	*	
—— ——, var.																					*	
—— flexuosus																			*	*	*	
—— Beaugrandi																				*	*	
—— Calisto																				*	*	
—— autissiodorensis																				*		
—— Gravesianus																					*	
—— Williamsoni																						*
—— arduennensis																						*
—— toucasianus																						*
75	4	3	7	4	1	2	3	7	5	7	4	12	4	10	4	5	5	5	3	10	12	8
	Lower Lias. 12.			Middle Lias. 14.					Up. Lias. 5.		Middle Oolite. 27.							Upper Oolite. 21.				= 79.

Note.—Localities Nos. 7, 8, 10, and 22 are West-coast patches.

[*To follow Table IV.*

and, arranged stratigraphically, and specially
Strata. This table, with that prepared to
vn history of the Northern Oolites.

	WEST COAST.								
Clay.	Raasay.		Skye.					Pabba.
Eathie.	Raasay Lower Lias.	Raasay Middle Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Oxford Clay.	Estuarine Oxfordian.	Pabba Middle Lias.
4 4	...	...	...	...	2 2			
...	...	...	1 1	...	...	...	...	1 1
...	...	1 2	1 2	...	...	...	...	1 2
...	1 1	...	...	...	1 1			
...	...	1 2	1 1	...	...	2 2		
...	...	1 1	1 1	...	...	...	2 2	
...	3 4	3 6	4 7	...	2 3	...	...	1 1
5 6	8 13	9 13	8 12	3 3	6 8	4 4	3 4	10 14
...	7 10	14 18	10 10	1 1	5 5	3 4	8 18	6 7
1 1	7 8	3 3	3 3	3 3	2 2	1 1	6 8	1 1
1 12	1 5	1 12	1 3	1 6	1 4	1 8	...	1 3
1 3	1 1	1 5	1 8	1 2	1 10	1 2	...	1 3
...	...	...	...	1 1				
2 2	...	...	...	...	...	...	1 1	
1 1								
15 29	28 42	34 62	31 48	10 16	20 35	12 21	20 33	22 32

TABLE V.—*Showing the entire known Fauna and Flora of the Jurassic patches on the East and West Coasts of Scotland, arranged stratigraphically, and specially showing the value of the Mollusca, without which little would have been determined as to the age of the Strata. This table, with that prepared to illustrate the distribution of the Ammonites through the Scotch Jurassic patches* (Table IV.), *shows the known history of the Northern Oolites.*

	EAST COAST.																	WEST COAST.							
	Rhætic.	Lower Lias.		Middle Lias.			Kella-way.	Oxford Clay.	Coralline Oolite.					Kimmeridge Clay.				Raasay.		Skye.					Pabba.
	Linksfield.	Dunrobin Reefs.	Inverugie.	Dunrobin Reefs.	Loch Spynie.	Lhanbryd.	Roof-bed, Brora.	Above Brora coal.	Cadh'-an-righ.	Braamberry Hill.	Left bank of Brora.	Ardassie.	Port-an-righ.	Alt-na-Cuil.	Alt Chollie.	Kintradwell.	Eathie.	Raasay Lower Lias.	Raasay Middle Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Oxford Clay.	Estuarine Oxfordian.	Pabba Middle Lias.
Plantæ	3/2	...	...	1/1	...	1/1	1/1	...	1/1	3/4	1/2	1/1	...	3/3	...	...	4/4	...	...	...	...	2/2			
Protozoa	...	...	...	...	...	...	...	...	...	...	...	1/1													
Cœlenterata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1/1	...	...	...	...	1/1
Asteroidea	...	...	...	...	...	1/1	...	...	...	...	...	...	...	...	...	3/3									
Crinoidea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1/2	1/2	...	...	...	...	1/2
Echinoidea	1/1	...	...	...	...	...	...	...	...	1/1	...	1/1	...	2/3	...	2/2	...	1/1	...	...	...	1/1			
Annelida	...	...	...	...	1/1	...	...	...	1/1	...	1/1	1/2	1/1	1/1	...	2/2	...	...	1/2	1/1	...	...	2/2		
Crustacea	2/2	...	...	...	1/1	...	...	...	...	...	...	...	...	...	...	...	...	...	1/1	1/1	...	...	...	2/2	
Brachiopoda	...	1/2	1/1	2/2	...	...	...	...	...	2/2	1/1	...	...	1/3	...	8/5	...	3/4	3/6	4/7	...	2/3	...	...	1/1
Monomyaria	3/3	6/12	8/13	6/11	6/9	7/10	7/15	4/4	5/6	12/23	7/16	7/16	4/4	6/10	1/1	7/15	5/6	8/13	9/13	8/12	3/3	6/8	4/4	3/4	10/14
Dimyaria	6/7	9/12	13/16	9/11	13/13	10/10	19/32	8/8	4/5	16/19	10/15	9/12	...	1/1	...	5/6	...	7/10	14/18	10/10	1/1	5/5	3/4	8/18	6/7
Gasteropoda	3/3	...	2/2	1/2	7/7	1/1	4/4	3/4	...	5/5	...	2/2	...	1/1	...	8/8	1/1	7/8	3/3	3/3	3/3	2/2	1/1	6/8	1/1
Ammonites	...	1/4	1/3	1/4	1/1	1/3	1/4	1/12	...	1/10	1/5	1/6	1/7	1/6	1/3	1/11	1/12	1/5	1/12	1/3	1/6	1/4	1/8	...	1/3
Belemnites	...	1/1	...	2/2	1/1	1/1	1/3	1/2	1/2	1/2	1/2	...	1/2	1/1	1/2	1/3	1/3	1/1	1/5	1/8	1/2	1/10	1/2	...	1/3
Nautili	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1/1				
Pisces	8/9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1/1	2/2	...	...	...	...	...	...	1/1	
Reptilia	2/2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1/1	1/1								
	27/29	17/31	25/35	21/32	30/33	22/27	33/59	17/30	12/15	41/66	22/42	23/41	7/14	17/28	3/6	33/57	15/29	28/42	34/62	31/48	10/16	20/35	12/21	20/33	22/22

Upper Lias and the Dogger above. No previous writer has dealt with the details of the Lower Oolites of Yorkshire with the same minuteness as Mr. Hudleston; and he has equally well marked out the higher members of the Jurassic group, which I shall have occasion to refer to at some length.

The Lower Oolites, as above stated, are divided into four groups. The base is known as the "Dogger" or Inferior Oolite. The *Lower Shale and Sandstones*, about 300 feet in thickness, succeed the Dogger; these are entirely estuarine, and contain no marine fauna; but an abundant cryptogamic flora must have occurred inland near where these sandy shales were deposited. Capping these Lower Estuarine arenaceous beds, is the first marine horizon above the Dogger, known by the name of the "*Millepore bed*;" this may possibly belong to the same series, or it may be correlated with the Whitwell Limestones of the Howardian Hills. It is traceable under varying conditions through the western and northern areas, either through its oblique lamination, or the comminuted condition of its fossil contents; the Bryozoon *Spiropora (Millepora Cricopora) straminea* everywhere characterizes this bed, whence the name. No less than 22 genera and 36 species of Bivalves have been determined from the "Millepore bed," 8 genera and 9 species of Gasteropoda, and 4 genera and 4 species of Echinoidea, besides species of other and lower groups; the most abundant fossils are *Lima duplicata*, *Tr.-gonia reticosta*, *Ceromya Bajociana*, *Myacites recurva*, *Pholadomya Heraulti* and *P. Sæmani*. *Pygaster semisulcatus* is the chief Echinoid; and *Gonioseris angulata* is the only Coral known. Mr. Hudleston believes that it is more than probable that the "Millepore group" may represent the "Cave Oolite," and consequently the "Lincolnshire Limestone;" and the presence of the *Lower and Upper Estuarine series* in Lincolnshire, and their great extension northwards into Yorkshire, above and below the Millepore series, furnishes good and reasonable grounds for this supposition. The Scarborough or Grey Limestone, in some places, is less than 100 feet above the Millepore series; and the intervention of the plant-beds goes far to show the shallowness of the area that underwent so many alternations of level. The Grey Limestone may, under modification, represent the zone of *Am. Humphresianus* or the upper portion of the Lincolnshire Limestone; but the Yorkshire type has not yet been detected south of the Humber. The fossils of the Dogger and Millepore bed are numerically given in a subsequent Table (VII. p. 84), side by side with those of the Grey Limestone and the Cornbrash; their numbers are expressed here by the formula I have adopted; they are for the Dogger $\frac{45}{76}$, the Millepore bed $\frac{36}{51}$, the Grey Limestone $\frac{48}{75}$, and the Cornbrash $\frac{71}{145}$. Thus, so far as collecting goes, the Dogger and the Grey Limestone are equally prolific, though the fauna differs. The poverty of the Cephalopoda is strikingly shown in this Table; yet the largest species of Belemnite (*B. giganteus*) in the British rocks occurs in the Grey or Scarborough limestone. Above the principal "Carbonaceous" groups of the Lower Oolites is the "Middle Shale and Sandstone series," above the Millepore beds, and below the Scar-

borough or Grey Limestone; these shales occupy a wide-spread area, and with them also the "Coal" seam, which uniformly occupies the area from the coast inland as far as Castleton in the N.W., and Coxwold in the S.W. That a bed no thicker than this should yet maintain itself over such an extensive district points to a remarkable uniformity of condition throughout a great part of the area now occupied by the Yorkshire Oolites at the period of deposition (Hudleston, *loc. cit.* p. 310). The occurrence of marine fossils in the Middle Shales is extremely rare; but one or two Monomyarian Bivalves have occurred. A large flora, including *Equisetaceæ*, *Lycopodiaceæ*, *Filices*, *Cycadaceæ*, and *Coniferæ*, occurs in the Lower and Middle Shales—about 50 species in the Middle Shales of Gristhorpe, 10 at Cloughton Wyke, and 30 in the Lower Shales of Hayburn Wyke and Whitby &c.; hence the persistent band of coal in the Gristhorpe beds or Middle Shale, which had such an extensive geographical range. This band of coal, averaging about 12 inches thick, doubtless is due to the growth and decomposition of this flora *in situ* along the shallow shore of an estuary whose area can be defined by the lateral extent of the present plant-bearing shales. The following Table (VI. p. 83) gives all the genera known in the shales below the Scarborough or Grey Limestone.

Above the Middle Sandstones and Shales is the *Grey Limestone*, or *Scarborough Limestone*, or the *second marine group* above the Dogger. This, again, consists of marine and estuarine beds having special features and organic contents, consisting of a large fauna comprising 48 genera and nearly 80 species. Cloughton Wyke, Hundale, and the scars south of Scarborough exhibit these singular beds with the utmost clearness, and richly fossiliferous. That these beds *represent* the zone of *Am Humphresianus* and *Parkinsoni*, or the middle and upper part of the Inferior Oolite of Gloucestershire, there is little doubt; they hold a fauna partly of their own, of a northern rather than southern type, yet many species in common with the southern true Inferior-Oolite Limestone. This important marine horizon in the midst of the estuarine shales and sandstones, with here and there a freshwater shell *(Anodon)*, is most ably described by Mr. Hudleston. I have collected largely from both the Hundale and Scarborough sections, and am enabled to follow and verify his clear descriptions.

The fauna of the Grey Limestone may be thus generalized:—

	Genera.	Species.
Belemnites	1	1
Ammonites	1	4
Gasteropoda	9	14
Monomyaria	11	18
Dimyaria	19	27
Annelida	2	4
Brachiopoda	1	1
Echinoidea	2	3
Asteriadæ	2	3
	48	75

TABLE VI.

Genera.	Number of species.	Middle Shales.		Lower Shales.	
		Gristhorpe Mid Shales.	Cloughton Mid Shales.	Hayburn Wyke.	Whitby Saltwick.
EQUISETACEÆ.					
Equisetum	2	2	2	1	
LYCOPODIACEÆ.					
Lycopodites	1	......	1	1	
FILICES.					
Solenites	2	1	1	1	
Baiera	2	2			
Cyclopteris	2	Scaleby			
Dichopteris	2	......	......	1	1
Phlebopteris	8	8			
Glossopteris	1	1			
Marzaria	1	......	......	......	?
Tæniopteris	3	3	......	......	1
Pecopteris	18	10	4	4	
Sphenopteris	13	3	1	8	3?
Ctenis	1	1			
CYCADACEÆ.					
Odontopteris	1	1			
Otozamites	10	2	......	5	4
Williamsonia	1	......	......	......	1
Zamites	1	......	......	1	
Pterophyllum	9	8	......	1	1
Cycadites	1	......	......	......	1
CONIFERÆ.					
Brachyphyllum	1	......	......	1	1
Thuytes	1	1			
Walchia	1	1	1		
Cryptomerites	2	2			
Taxites	1	1			
Araucarites	1	1			
Total	86	49	10	24	13

The Cephalopoda are rare in all the beds of the Lower Oolites of Yorkshire, between the Upper Lias and the Kellaways Rock; in the Oxfordian stage the species are greatly augmented. The Belemnite in the Grey Limestone is the large and well-known form *B. giganteus*; and the Ammonites are *A. Humphresianus*, *A. Blagdeni*, and *A. Braikenridgii*. It is very doubtful if *Am. Parkinsoni* has ever been found in Yorkshire, although it is said to have occurred.

TABLE VII.—*Fauna of the Dogger, Millepore-bed, and Grey Limestone and Cornbrash of Yorkshire.*

		Dogger.	Millepore bed.	Grey Limestone.	Cornbrash.
Cephalopoda.	Belemnites	......	......	$\frac{1}{1}$	$\frac{1}{1}$
	Ammonites	......	......	$\frac{1}{4}$	$\frac{1}{1}$
	Nautilus	......	......	......	$\frac{1}{1}$
	Gasteropoda	$\frac{13}{27}$	$\frac{8}{9}$	$\frac{9}{14}$	$\frac{15}{17}$
Lamellibranchiata.	Monomyaria	$\frac{7}{11}$	$\frac{6}{14}$	$\frac{11}{18}$	$\frac{13}{34}$
	Dimyaria	$\frac{23}{36}$	$\frac{16}{22}$	$\frac{19}{27}$	$\frac{24}{68}$
	Brachiopoda	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{2}{5}$
	Annelida	......	......	$\frac{2}{4}$	$\frac{2}{3}$
	Bryozoa	......	$\frac{1}{1}$	......	$\frac{4}{5}$
	Echinoidea	......	$\frac{4}{4}$	$\frac{2}{3}$	$\frac{4}{6}$
	Asteroidea	......	......	$\frac{2}{3}$	
	Cœlenterata	......	......	......	$\frac{2}{2}$
	Protozoa	......	......	......	$\frac{2}{2}$
	Total	$\frac{45}{76}$	$\frac{36}{51}$	$\frac{48}{75}$	$\frac{71}{145}$

The above Table (VII.) shows that in the Cornbrash of Yorkshire, as in the Lincolnshire Oolites and beds below, the Cephalopoda are scarcely represented; also that only two Actinozoa are known; and that, unlike the southern Cornbrash, only five species of Brachiopoda occur in this northern extension.

The *Upper Shales and Sandstones*, about 140 feet thick, with only one or two fossil shells, rest upon the Grey Limestone; and south of the Spa their remarkable bedding, enormous "dogger" and siliceous rocks, are the marked features. At Gristhorpe Bay they are also conspicuous; they may be, and probably are, "the moor stones, whose weird and grey masses on the Yorkshire moors seem to live on unchanged and unaltered under the test of meteoric vicissitudes scarcely known in any other region."

The *Cornbrash*.—This capping to the Lower Oolites, although only a few (3 or 4) feet thick, is the most fossiliferous zone of the entire series; it is the most persistent band or horizon of the Jurassic subdivisions in Yorkshire; and it suddenly exhibits an

assemblage of life hitherto unprecedented in the British rocks. Based upon sandstone utterly void of organic remains, and covering a vast geographical area, the grey subcrystalline limestone of the Cornbrash tells its own tale. It is the landmark of the practical geologist; it terminates the vast arenaceous barren estuarine beds which so conspicuously characterize the Lower Jurassic rocks of Yorkshire; it is at the base of the Oxfordian group, which commences with the Kellaways beds resting immediately on the Cornbrash. Whether the Cornbrash exists in the Cave district, below the thickly developed Kellaways sands, we have yet to learn; its occurrence in Lincolnshire in the Brigg district is certain, but it exists under a very different lithological aspect; and so does the Kellaways. The Molluscan fauna of the Yorkshire Cornbrash is large and important: with it cease most of the Lower-Oolite species. The appended Table (VII.), including the Cornbrash, numerically exhibits all the species occurring in Yorkshire, and may be a fit termination to the fauna of the Lower Oolite of the Yorkshire coast. I also state the numerical value of the species in the following list:—

	Genera.		Species.
Belemnites	1	....	1
Ammonites	1	....	1
Nautilus	1	....	1
Gasteropoda	15	....	17
Monomyaria	13	....	34
Dimyaria	24	....	68
Brachiopoda	2	....	5
Annelida	2	....	3
Bryozoa	4	....	5
Echinoidea	4	....	6
Cœlenterata	2	....	2
Protozoa	2	....	2
	71	....	145

The Lower Oolites are estimated by Mr. Hudleston to measure nearly 1000 feet in thickness as exposed along the coast; but nowhere in the interior of the county are the horizons sufficiently exposed to warrant a true estimate. Commencing with the Dogger, they are, as given by the author:—

1. Dogger and sands (Blue Wyke)	80	feet.
2. Lower Shale and Sandstone (Peatt)	280	,,
3. Millepore-bed (Cloughton)	12	,,
4. Middle Shale and Sandstone (Cloughton)	100	,,
5. Scarborough Limestone (Cloughton)	50	,,
6. Upper Shale and Sandstone (Spa Cliffs)	160	,,
7. Cornbrash and shales (Gristhorpe)	13	,,
	695	,,

Mr. Hudleston thinks that perhaps these thicknesses are only partially maintained in the moorland chain; whilst in the inland or

Howardian chain a very different development is observed. He submits a section of the latter in the valley of the Derwent, south-west of Malton, as an example or type of the whole: this is elaborately discussed, and forms an important part of Mr. Hudleston's researches upon the Lower Oolites.

Continuous with part 1, but in the following year, 1875, the higher members or subdivisions of the Yorkshire Oolites are critically worked out: they consist of six subdivisions, two of which are partly new; these are the "shales with *Avicula echinata*," and the uppermost or "supracoralline rocks." All are seen along the coast. These six subdivisions are:—

1. The Shales with *Avicula echinata*.
2. The Kellaways Rock.
3. The Oxford Clay.
4. The Lower Calcareous Grit.
5. The Coralline Oolite.
6. The Supra-Coralline beds.

The Shales with *Avicula echinata*, not very distinct from the Cornbrash, Mr. Hudleston regards as anticipating in a measure the physical conditions of the Oxford Clay, but interrupted for a time by the intervention of the great arenaceous deposit of the Kellaways series. At Scarborough they are from 12 to 15 feet thick, in Newton Dale 10 feet. They may be the Hambleton argillaceous beds of Phillips at the base of the Kellaways; possibly, also, as suggested by Hudleston, the "*Avicula-echinata* beds" of Porta Westphalica, in Germany, may be of the same age and position, although it is here von Seebach draws the line between the Middle and Upper Jura. Dr. Brauns extends that line to the top of the "*Ornatus* clays," which have their equivalents in the highest part of the Kellaways Rock of Scarborough.

Fourteen species of fossils are recorded from these shales—4 genera of Monomyaria with 7 species, 4 genera of Dimyaria with 4 species, *Waldheimia lagenalis*, *Rhynchonella Leedsii*, and *Glyphea Stricklandi*. All of these except the two last-named species have a wide Jurassic range.

No description of the Kellaways Rock ever given approaches the physical history and palæontological analysis given by Mr. Hudleston. The sections are detailed bed by bed; and I am happy to be able to follow him in detail, from personal examination, though not with a knowledge equal to his own. The great mass of the fossils occur in the upper ferruginous hard rock and the upper tier of solid stone, in which *Belemnites Owenii* and *Gryphæa dilatata* occur abundantly, with the Ornatus Ammonites *A. Gowerianus*, *A. Duncani*, *A. Jason*, *A. Gulielmi*, *A. gemmatus*, &c. &c. The group Cordati, *A. Lamberti*, *A. cordatus*, *A. flexicostatus*, &c., indeed most of the fossils, especially the Ammonites, are from the subcrystalline rock, or "upper tier." The conditions of this rock are traced along the coast from the Castle Hill, Scarborough, to Newbiggin Wyke at Gristhorpe Cliff, where it thins out and is lost, having, in $5\frac{1}{2}$

miles become reduced from 75 feet to 5 feet. This "attenuation gives a gradient of 1 in 415 for natural slope of the upper surface" (Hudleston, *loc. cit.* p. 367). The grand section and precipices of the Kellaways Rock at Yewdale Scar in Newtondale, 8 miles W. by N. of Hackness, is graphically described; and his bold speculations as to its association with the Oxford Clay and Coralline beds are of much significance. A sectionis devoted to the fossil contents of the Kelloway rocks. Mr. Hudleston points out, and that truly, that the fauna "of the upper part of the Kelloway rock of Yorkshire, as indicated by its Ammonites, embraces much of the Oxfordian of English geologists." The question then arises, "Are the fossiliferous Cephalopoda-beds in the upper part of the Kelloway rock at Scarborough, at Red Cliff, and at Gristhorpe wholly contemporaneous deposits?" At Scarborough, species of the group Ornati are plentiful, and at Gristhorpe the Cordati, especially *Am. Lamberti* and *A. vertumnus* &c. The accompanying is, I believe, a nearly complete generalized list of the fauna of the Kellaways Rock of Yorkshire:—

Belemnites		2	species.
Nautilus		1	„
Ammonites		40	„
Gasteropoda	11 genera	17	„
Monomyaria	11 „	23	„
Dimyaria	19 „	44	„
Brachiopoda	4 „	4	„
Crustacea	1 „	1	„
Fish	1 „	1	„
	50	133	

Nautilus hexagonus stands alone in the northern Kellaways, and *Bel. Owenii* and *B. hastatus* are, individually, abundant. These two species have been found at the new exposure of the Kellaways Rock at North Cave, where I found *Am. Gowerianus* and *Am. vertumnus* associated with them, and hundreds of *Gryphæa dilatata* and *Pinna cuneata* lower down. About 20 species of Lamellibranchiata and 5 Gasteropoda pass to the Oxford Clay; these numbers apply to the group generally, and for all British localities.

A marked and striking feature in the Kellaways Rock of Yorkshire is the sudden appearance and abundance of its Ammonites. *Whence came they?* Bearing in mind that only one species is found in the underlying Cornbrash, and two or three in the Lincolnshire Limestone, and here we have 40, 39 of which never appeared before or in lower beds in Britain, as Mr. Hudleston remarks, it was "a regular invasion and nothing less." He suggests that "probably this great sandbank was deposited during a subsidence of this region far more continuous in time and extended in space than those more partial depressions which, during the period of the Lower Oolites, had in this region intercalated the spoils of the sea with those of the estuary and marsh. This more continuous descent seems at length to have removed or lowered barriers which had

hitherto kept out the waters of a sea swarming with strange Cephalopoda" (Hudleston, *loc. cit.* p. 374). I estimate the number of genera in the Kellaways Rock of England at 51, and the species at 166. They will be discussed under the tabular analysis.

Oxford Clay.—This is grandly shown north of Filey Brig, at Gristhorpe and Clayton Bays, capped by the bold cornice of the Lower Calc Grit, sweeping down in a gentle curve or slope to the shore; its thickness generally may be assumed to be from 130 to 150 feet.

The entire fauna is a poor one; but the Cephalopoda and Dimyaria exceed all other groups numerically. Forty-five species of Ammonites are known in Britain, and twelve or fourteen species in Yorkshire. The whole fauna for England and Scotland, including the Staffin Shales &c., is as follows:—

	Genera.		Species.
Plantæ	1	....	1
Protozoa	3	....	3
Cœlenterata (none).			
Echinodermata	3	....	3
Annelida	2	....	2
Crustacea	5		6
Bryozoa (none).			
Brachiopoda	5	....	10
Monomyaria	9	....	26
Dimyaria	21	....	48
Gasteropoda	10	....	17
Ammonites	1	....	45
Ancyloceras	1	....	1
Nautilus (none).			
Belemnites	1	....	13
Teuthidæ	2	....	2
Pisces	3	....	4
Reptilia	7	....	13
	74	....	194

Subsequent to the Lias, no period in the early history of the Jurassic seas of Britain presents us with such an assemblage of Ammonites. The Lias yields 220 species, the Inferior Oolite 42, the Great Oolite 7, the Kellaways Rock 40, and now we have present in the Oxford Clay 45 species, 18 or 20 of which are probably common to it and the Kellaways below. The Oxfordian stage doubtless yields the most ornate Ammonites in the British strata, not even excepting the Gault. No species of *Nautilus* has yet occurred in the Oxford Clay, either in Yorkshire or elsewhere in England. So much is said in Mr. Hudleston's paper upon the fauna of the Oxfordian stage and the particular species that characterize the two subdivisions, that comment on my part is needless. I recommend all interested in Jurassic geology to master the details therein given. There is much to be done with regard to the palæontology of the Oxford Clay and the range or vertical distribution of its organic

contents. The upper beds are unfossiliferous; and, as Mr. Hudleston states, "for purposes of comparison with N.W. Germany, if it may be deemed proved from negative evidence that the Ornati do not occur higher than the top of the Kelloway rock, we must look upon this great thickness of beds as belonging quite as much to the Upper as to the Middle Jura of that country."

The fossils given in Mr. Hudleston's paper are numerically as follows, and represent only 7 classes:—

	Genera.		Species.
Belemnites......	1	....	3
Ammonites	1	....	11
Gasteropoda	4	....	5
Monomyaria	6	....	10
Dimyaria	11	....	13
Brachiopoda	2	....	2
Crinoidea			traces.
	25	....	44

Lower Calcareous Grit.—The mass of material gone over by Mr. Hudleston for this and the Corallian group can only be estimated by those who know the rocks and the area they occupy. The Oxford Clay in its uppermost limit becomes gradually more sandy; the typical Lower Calcareous Grit commences with induration, and forms a "mural cap of hard yellow rock" to the grey underlying Oxford Clay. It is seen in the tabular range, the Howardian hills, in Castle Howard and Hovingham Park, &c. The subdivisions are petrological, not palæontological. Mr. Hudleston states that, "taken all together, the Lower Calcareous Grit occupies more ground in Yorkshire than any other member of the series between the Lower Oolites and the Kimmeridge Clay." That the Calc Grit constitutes the base of the Corallian series, and represents the commencement of the "White Jura" of the continent, there cannot be any doubt. Physical conditions had and have more to do with determining the Molluscan life over a given area than perhaps any other cause. That this was the case with the Passage-beds into the Coralline Oolite seems highly probable. Mr. Hudleston appends a list of Lower Calc Grit fossils, which he says is by no means exhaustive, but intended to give a fair idea of the facies of the fauna (*loc. cit.* pp. 388–390 for specific names). The following statement indicates the numerical proportions of the genera and species:—

	Genera.	Species.
Belemnites	1	2
Nautilus	1	1
Ammonites	1	7
Gasteropoda	7	7
Monomyaria	7	12
Dimyaria	11	17
Brachiopoda	3	5
Crustacea	1	2
Annelida	1	1
Echinoidea	5	5
Asteriadæ	1	1
Crinoidea	1	1
Cœlenterata	2	2
Protozoa	1	2
Wood &c.	1	1
	44	66

Cayton Bay, Filey, and Pickering are the chief localities. Huge Ammonites characterize this horizon. The groups *Cordati*, *Armati*, and *Annulati* are conspicuous. The *Cordati* are represented by *Am. excavatus*, *A. Sutherlandiæ*, and *A. vertebralis*; the *Armati* by the type Ammonite of the formation, *A. perarmatus*; the *Annulati* by *Am. plicatilis*, which ascends to the Passage-beds. This singular Ammonite appears to be the *Am. triplicatus* of Sowerby, or *Am. ingens* of Young and Bird. I must refer for much valuable matter upon the distribution of the fossils to Mr. Hudleston's paper. He subsequently describes two special sections, the first being the Scarborough Castle Yard and Hill series, and the second the Filey Brigg section; they are models of field-work reduced to description. It has been my good fortune to examine every foot of these and other sections described by Mr. Hudleston. The paragraph upon the correlation of the Calcareous Grit amongst its members through the county is a great contribution to Corallian geology.

Mr. Hudleston's third communication is devoted to the *Coralline Limestones*, divided into five groups, commencing with—

1. The Lower Limestones, in 6 divisions.
2. { The Middle Calcareous Grit, in 1 division.
   The Coralline Oolite, in 3 divisions.
3. The Coral Rag, subzone of *Cidaris florigemma*, in 3 divisions.
4. The Supracoralline beds, in 3 divisions.

A Table giving the generalized scheme of the Coralline Limestones and associated beds is appended to the memoir, with every particular; separate lists are attached to each group and its subdivisions. The Coralline fauna occurring in the Lower Calc Grit, the Coralline Oolite, the Coral Rag, and the Supracoralline beds is large and general, numbering 120 genera and 295 species. The accompanying Table (VIII.) expresses the number of genera and species in the classes or groups. For the range of every species reference should be made to the Table in Mr. Hudleston's paper, *loc. cit.* pp. 481–494.

I regret that space will not allow me to analyze this memoir more fully; but to do so would necessitate the extraction of much matter. Ten new species are introduced or enumerated in the Table; 48 species came from older or lower beds, and 6 pass to the Kimmeridge Clay. The chapter upon the palæontology of the Coralline beds is worthy of close study; and to it I refer rather than make further comment.

TABLE VIII.—*Showing the Distribution of the Coralline Fauna through Yorkshire, illustrating Mr. Hudleston's researches.*

Classes.	Genera.	Species.	Lower Calcareous Grit.	Coralline Oolite.	Coral Rag.	Supracoralline Oolite.	Kimmeridge Clay.
Reptilia	4	4	3 3	4 4	1 1		
Pisces	5	6	1 1	3 3	1 1		
Ammonites	1	16	1 7	1 3	1 3	1 5	1 2
Belemnites	1	7	1 2	1 2		1 3	1 1
Nautili	1	2	1 1	1 1	1 1	1 1	
Gasteropoda	20	58	9 9	9 16	18 46	2 2	
Dimyaria	33	90	19 30	22 43	15 31	9 12	1 1
Monomyaria	15	54	8 22	10 32	9 30	6 8	1 2
Brachiopoda	3	8	3 5	1 1	2 3		
Bryozoa	1	1	1 1				
Echinoidea	13	19	7 8	6 8	11 15		
Crinoidea	3	5	1 2	1 1	3 3		
Asteroidea	1	1	1 1				
Crustacea	1	2	1 2	1 1	1 2		1 1
Annelida	2	5	1 3	1 1	1 2		1 1
Cœlenterata	9	10	4 4	2 3	7 9		
Protozoa	4	4	4 4	1 1	1 1		
Plantæ	3	3	2 2	3 3			
	120	295	68 107	67 123	72 148	20 31	6 8

The publication of Prof. Morris's valuable paper "On some Sections in the Oolite district of Lincolnshire" * constituted an important era in the history of the geology of the Midland districts. His views then expressed have, however, since received modification; for in 1869 he corrected his previous opinion, and came to the conclusion that the Lincolnshire Oolite as well as the Collyweston beds below belong to the Inferior Oolite †.

* Quart. Journ. Geol. Soc. vol. ix. p. 317 (1853).

† "Geological Notes on Parts of Northampton and Lincolnshire," Geol. Mag. vol. vi. p. 446 (1869).

Dr. Lycett, in 1850, on purely palæontological grounds, Mr. S. Sharp, of Dallington Hall, Northampton, Mr. Beesley, of Banbury, Prof. J. W. Judd, and the Rev. T. W. Norwood, through evidence in the "Cave" district, long ago came to the same conclusion on studying the northern prolongation of the Lincolnshire Limestone across the Humber—viz. that the fossil contents closely agreed with those of the Pea-grit or lowest member of the Inferior Oolite of Cheltenham.

Prof. Judd, in his exhaustive work on the geology of Rutland *, has cleared up in the most conclusive manner the relations existing between the several members of the Lower Oolite of the Midland counties; the vexed questions as to the age and position of the Northampton Sands, the Collyweston Slates, the Lincolnshire Limestone, the position and history of the Lower and Upper Estuarine beds, the distribution and correlation of the Great Oolite and its fossils, and the Great Oolite clay, are all ably worked out by the author. Prof. Judd has also dealt with the Lower, Middle, and Upper Lias and their subdivisions and modern nomenclature. The whole volume is an able exposition of the present aspect of Jurassic geology. In this memoir, besides the detailed description of the geological structure of the county of Rutland, Prof. Judd enters fully into the purely scientific questions connected with the history of the Jurassic rocks, especially those that characterize the Midland district of England, his investigations there between the years 1867 and 1871 leading him to propose a new nomenclature and classification for the Oolitic rocks of that area. Greatly was Mr. Judd aided by Mr. S. Sharp, whose large local collection and extensive and accurate knowledge of the county were both placed at his disposal. The two memoirs by Mr. Sharp upon the Northamptonshire Oolites already noticed ably maintained and exemplified the views of Mr. Judd.

The first thirty-two pages of Prof. Judd's memoir are devoted to the three divisions of the Lias, with a tabular correlation and arrangement of the several known classifications:—

1. The English classification.
2. Continental.
3. Divisions of Quenstedt.
4. Ammonite Zones (16).

This, as showing the received nomenclature and accepted zonal classification according to the Ammonitidæ, I deem it important to give here with some modifications (Table IX.):—

* Mem. Geol. Survey of England and Wales, Geology of Rutland and parts of Lincoln, Leicester, Northampton, &c. By J. W. Judd, F.G.S., with Appendix and Tables of Fossils by R. Etheridge, F.R.S., 1875.

TABLE IX.

English classification.	Continental classification.	Divisions of Quenstedt.	Ammonite zones.	Subdivisions.	Characteristic Fossils.*
		Lias ζ	Zone of *A. jurensis*	1	A. jurensis.
Upper Lias	Upper Lias	Lias ε	Zone of *A. communis*	5	A. communis, A. annulatus, A. Holandrei, A. serpentinus, A. A. bifrons, Leda ovum, Belemnites compressus, Myacites donaciformis, Inoceramus dubius.
			Zone of *A. spinatus*	1	A. spinatus, Bel. paxillosus, Rhynchonella tetrahedra, Terebratula punctata.
Middle Lias	Middle Lias	Lias δ	Zone of *A. margaritatus*	4	A. margaritatus, A. Normannianus, Bel. elongatus, Plicatula spinosa, Cardium truncatum, Lima pectinoides, Myacites unioides.
			Zone of *A. capricornus*	1	A. capricornus, Leda complanata, Cardium truncatum.
		Lias γ	Zone of *A. ibex*	1	A. ibex.
			Zone of *A. Jamesoni*	2	A. Jamesoni.
			Zone of *A. armatus*	1	Hippopodium ponderosum.
		Lias β	Zone of *A. oxynotus*	1	Pentacrinus, Bel. clavatus.
			Zone of *A. obtusus*	1	Cardinia gigantea, C. Listeri.
Lower Lias	Lower Lias		Zone of *A. semicostatus* (*A. geometricus*, Oppel)	1	Plicatula spinosa.
		Lias α	Zone of *A. Bucklandi*	1	Lima gigantea, Gryp. incurva.
			Zone of *A. angulatus*	1	Cidaris Edwardsii.
			Zone of *A. planorbis*	2	Lima Hermanni, Rhyn. variabilis.
Keuper?	Infralias? (in part).	....	Penarth (Rhætic) or zone of *Avicula contorta*	2	Pecten valoniensis, Cardium rhæticum, Axinus cloacinus.

* For the strata exhibited in the districts described in Prof. Judd's memoir (see p. 89, *loc. cit.*) I have appended some characteristic fossils instead of the localities for beds &c.

One or two of these zones, although present, are not fully represented in Rutland; such appears to be the case with the zone of *Am. obtusus*; but, taking type localities for our guide, each zone is, in its geographical place or locality, characteristically shown. This obscurely developed Obtusus series in Rutlandshire is at Lyme Regis a marked and important horizon in the Lower Lias. The same may be said of the zone of "Ibex" in Somersetshire; it is well developed, and known under the name of *A. Boblayei*. This and the zone of *Am. Jamesoni* are often united*.

The thirty-two pages in Prof. Judd's memoir devoted to the Lias, demonstrate the value of the above divisions, and enable the student to correlate the English Lias with that of the continent. The zones of *Am. Murchisonæ*, *Am. Humphresianus*, and *Am. Parkinsoni* equally in their order characterize the Inferior Oolite, *Am. gracilis* the Great Oolite, and *Am. discus* and *macrocephalus* the Cornbrash; the preceding formations are all equally capable of zonal subdivision by means of their characteristic Ammonites.

The chapter devoted to the Lower Oolites sets forth the received subdivisions, and establishes the grouping of the Inferior Oolite into two members, the lower being chiefly arenaceous, and constituting the "Northampton Sand;" while the upper division is almost purely calcareous, and is distinguished by the name of the "Lincolnshire Oolite Limestones." Here and there, at the junction of these two groups, there occur beds of fissile sandy limestone. These slaty beds constitute the "Collyweston Slates," hitherto wrongly referred to the base of the Great Oolite.

The Great Oolite strata are divisible into four groups:—

No. 1, or the highest, being the Cornbrash.
2, the Great Oolite Clay = the Forest Marble of the south of England.
3, the Great Oolite Limestones.
4, the Upper Estuarine marls &c. which represent the Stonesfield Slate or lower zone of the Great Oolite of the south of England.

Beneath these Upper Estuarine beds comes the Lincolnshire Limestone, containing the characteristic fossils of the lowest division, or the Inferior Oolite of the south-west of England. Succeeding the above, or forming its lowest member, is the Northampton Sand, associated with which in the upper part is the Lower Estuarine series. The Northampton Sand often reposes upon an eroded surface of Upper Lias clay. The fossils of the Lower Ironstone are all marine†. Forty-eight pages are devoted to the origin, general features, lithological characters, microscopical structure, and mode of formation of the Northamptonshire iron-ore.

The following list exhibits the number of fossils of the Ironstone

* *Vide* paper by E. B. Tawney, M.A., Proc. Bristol Nat. Soc. 1875.

† The largest collection ever made of the fossils of this series was by Mr. S. Sharp, F.G.S., and chiefly from Duston and other points near Northampton.

bed, nearly every species in which was named and catalogued in Mr. Sharp's collection by myself. The whole series in Mr. Sharp's collection clearly determined the horizon to which they belong.

Plantæ	1	species.
Cœlenterata	none.	
Asteroidea	1	,,
Echinoidea	1	,,
Annelida	2	,,
Crustacea	none.	
Bryozoa	none.	
Brachiopoda	none.	
Monomyaria	14	,,
Dimyaria	22	,,
Gasteropoda	4	,,
Belemnites	1	,,
Ammonites	none.	
Nautilus	1	,,
	47	

The Lincolnshire Limestone, formerly believed to be the equivalent of the Great or Bath Oolite, is now, on undoubted stratigraphical and palæontographical evidence, known to be true "Inferior Oolite." In almost every locality where the beds are exposed, they exhibit different characters. Under two facies or "aspects," however, the formation is specially recognized; and Prof. Judd has designated them the "coralline facies" and the "shelly facies." Compact subcrystalline argillaceous limestones, slightly oolitic in texture and abounding in corals, characterize the first or "coralline" beds, which yield *Thamnastrœa*, *Montlivaltia*, *Isastrœa*, *Latimœandra*, &c.

An abundant molluscan fauna accompanies these corals, especially *Nerinœœ*. The well-known *Natica cincta* [*N. leckhamptonensis*], *Pholadomya fidicula*, *P. Heraulti*, *Ceromya bajociana*, *Pinna cuneata*, *Modiola Sowerbyana* [*M. plicata*], &c. abound.

The second type, or "shelly facies" is composed chiefly of comminuted, waterworn fragments of shells, broken and eroded. These dead-shell beds or banks were accumulated under the influence of varying currents. They contain *Cerithium*, *Trochus*, *Turbo*, *Astarte*, *Ostrea*, *Lima*, *Trigonia*, *Terebratula*, &c., and remains of Echinodermata. It will also be seen by the tabular analysis of the fauna that there is an almost total absence of the Cephalopoda; there are two or three species of Belemnites and *Nautili*; and the Ammonites are reduced to four or five species. *Bel. acutus*, *B. Blainvillii*, and *B. canaliculatus*, with *Nautilus obesus*, *N. polygonalis* and the four Ammonites, *A. Blagdeni* (rare), *A. Murchisonœ*, var., *A. subradiatus*, and *A. terebratus*, constitute all the Cephalopoda yet known to occur in the Lincolnshire Limestone.

The *freestone* beds of the south-west of England exhibit the same

paucity of fossils, and evidently were originally deposited under the same or similar conditions. It is evident that the great mass of the Lincolnshire Oolite was accumulated and deposited under moderately deep-water conditions. The lower members, however, exhibit transitional conditions towards those of the underlying Estuarine series. The Arenaceous beds contain much wood and the remains of ferns, especially *Polypodites Lindleyi*, Göpp. (*Pecopteris polypodioides*, Lindl.), the whole resembling the conditions prevailing in the Lower Sandstones and Shales of east Yorkshire. It is at the base of these arenaceous beds that the fissile "Collyweston slates" occur, whose position was long misunderstood; they were wrongly assigned to the horizon of the Stonesfield slate, below the true Great Oolite. That these remarkable beds were accumulated under littoral conditions, or in close proximity to the shore, their fossil contents clearly prove. Upwards of 50 species characterize these slates, including 6 Gasteropoda and 46 bivalves (26 of which are Monomyarian and 20 Dimyarian forms). No mammalian, reptilian, or insect remains (so characteristic of the Stonesfield Slate) have occurred; nor do I know of any Brachiopoda. One important univalve, "*Pterocera Bentleyi*," essentially characterizes the deposit; it ranges into the limestone above, but is rare. Of bivalves we find *Gervillia acuta*, *Pinna cuneata*, *Trigonia compta*, *Lucina Wrightii*, *Myacites scarburgensis*, *Cardium Buckmani*, *Pholadomya fidicula*, and *P. ovalis*; *Pecten lens* and the beautiful fern *Polypodites Lindleyi* specially characterize these slates below the Lincolnshire Limestone. Numerically the fauna is thus expressed:—

	Genera.	Species.
Gasteropoda	5	6
Dimyaria	12	26
Monomyaria	10	20
Asteroidea	1	1
	28	53

The following Table (X.) exhibits the chief localities where the Lincolnshire Limestone occurs according to Prof. Judd's memoir, and the fauna of each locality, the genera and species expressed, as in my former Tables, by means of two factors within the square, showing both zoological groups in the column headed by the locality, the upper figure indicating the number of genera, and the lower the number of species in each locality.

TABLE X.—*Distribution of Genera and Species in the Lincolnshire Limestone from 8 chief localities, and the Collyweston Slate at the base.*

Classes.	Weldon.	Wakerley.	Marly bed, Stamford, Squire's stone-quarry.	Stamford.	Wild's Ford.	King's Cliffe.	Stibbington.	Whittering.	Collyweston Slate.
Reptilia				1 1					
Pisces			2 3	2 2					
Ammonites				1 4					
Nautili				1 2					
Belemnites..................			1 1	1 2		1 1		1 1	
Gasteropoda	5 10	1 3	4 9	5 12	2 3	3 5	9 14		4 6
Dimyaria	5 6	7 13	16 25	14 30	8 10	10 18	7 10	3 4	12 26
Monomyaria	1 2	6 15	4 12	5 16	3 7	6 13	7 12	6 12	10 20
Brachiopoda	2 2	1 1	2 2	2 7	1 1	2 4	2 5		
Bryozoa		1 1							
Crustacea............ none									
Insecta............... none									
Annelida		1 2		1 1		1 3	2 2		1 1
Echinoidea	1 1	3 4	2 2	4 4		3 3	3 5		
Crinoidea							1 1		
Asteroidea									
Actinozoa	1 1	3 3	3 3	6 6	1 1	1 1			
Protozoa									
Plantæ			3 3	2 2			1 1	1 1	1 1
	15 22	23 42	37 60	45 89	15 22	27 48	32 50	11 18	28 54

Careful examination of this Table shows the extreme paucity of the Cephalopoda in the Northamptonshire and Lincolnshire deposits as compared with beds of the same age in Gloucestershire, Dorsetshire, and Somersetshire, or the south-west of England. There are only two species of *Nautilus*, *N. obesus* and *N. polygonalis*, and two species of Dibranchiata, *Belemnites acutus* and *B. bessinus*; and the latter species occurs in all four localities. Still more striking is the dearth of the great group of the Ammonitidæ; only four species seem to occur, and these in one locality near Stamford: they are *Ammonites Murchisonæ*, *A. subradiatus*, *A. terebratus*, and an undescribed species. The Gasteropoda, with very few exceptions, are also different from any of the southern types, and differ equally from most of the Yorkshire forms, the Stibbington fauna mostly resembling the Dogger

series. The Lamellibranchiata, in both groups, differ little from the southern facies, the large fauna in the Stamford area uniting many of the species. Compared also with Gloucestershire and Dorsetshire, the Brachiopoda are not abundant, and the same species prevail everywhere. Only one Bryozoon is named in the collection made, and this (*Cricopora* or *Spiropora straminea*) is the well-known form occurring in the Millepore-beds of Yorkshire. The Echinoidea, species for species, are the same as those occurring all through the Cotteswolds; they equally help us to fix the age of the Cave beds north of the Humber, determining them to be but an extension of the Lincolnshire Oolite across the Humber. The Coralline group of Judd seems best developed in the Stamford area, south of the Nene, and in the Barnack rag. Taking the localities in the order of their productiveness and according to the collections made, they may be represented in the following list:—

Stamford	45	genera and	88	species.
Marly series, Squire's quarry	37	,,	59	,,
Collyweston beds	27	,,	54	,,
Stibbington	32	,,	50	,,
King's Cliff	27	,,	48	,,
Wakerley	23	,,	42	,,
Wild's Ford	13	,,	32	,,
Weldon	15	,,	22	,,
Wittering	10	,,	18	,,
	229		413	

These numbers give a mean of distribution for the genera of 25, and for the species of 46. So much care was bestowed upon the collecting, through the agency of Mr. Judd, that we may accept the faunal value of the species in each locality as being practically exhaustive. In the appendix to Prof. Judd's memoir, compiled by myself, will be found on pp. 276–283 a detailed specific list of every species then known as occurring in that area in the Lincolnshire Oolite, Collyweston Slate, and Northampton Sand. The faunas of these 3 groups or horizons were compared amongst themselves, then with the Inferior Oolite in the south of England and Yorkshire, and then with the Great Oolite of the west of England. The result of this analysis is an important one, and clearly shows that the Lincolnshire beds are far more nearly allied to those of the south of England than to the Yorkshire Oolites. It is expressed in figures in the following Table (XI.). The Midland or Northampton and Lincolnshire Inferior Oolite, in its 3 divisions, occupies the first 3 columns; those to the right hand are compared or correlated with the Midland group.

TABLE XI.

	Inferior Oolite of the Midland district.			Compared with		
	Lincolnshire Limestone.	Collyweston Slate.	Northampton Sand.	Inferior Oolite of the South of England.	Inferior Oolite of Yorkshire.	Great Oolite of the West of England.
Plantæ	6	1	1	...	2	2
Cœlenterata ...	21	...	7	17	1	9
Echinoidea	19	1	11	17	5	7
Annelida	8	...	3	6	5	
Crustacea	1	...	1			
Bryozoa	...	...	...	1	1	
Brachiopoda ...	26	1	24	18	1	3
Monomyaria ...	55	31	55	50	18	30
Dimyaria	101	32	90	63	42	54
Gasteropoda ...	56	5	29	33	15	27
Ammonites	4	...	8	6	1	
Belemnites	4	...	8	3	2	
Nautili............	2	...	4	2		
Pisces	2	...	...	...	...	1
Reptilia	1	...	2			
	306	71	243	216	93	133

Thus, out of the 306 species occurring in the Lincolnshire Limestone, 71 are in the Collyweston Slate below, 243 of the 306 occur in the Northampton Sand, 216 species are common to the Oolites of the South of England, whilst only 93 can be identified in the Yorkshire beds, but 133 of the Lincolnshire Inferior Oolite species pass upwards and are found in the Great Oolite of the West of England. I am, however, disposed to regard this last number as too high; the condition of the shells is such, in some localities and beds, as to render them difficult of strict identification and comparison.

The rocks of the two facies of the Lincolnshire Limestone are not constant in their relative positions; and this change of conditions is doubtless due to difference of level of the sea-bed at the time of deposition. There is no doubt that the great mass of the Lincolnshire Oolite was accumulated under moderately deep-water conditions; but both estuarine and littoral conditions prevail at its base and top. Prof. Judd believes* that "during a portion of the Jurassic period, well marked within the ancient life-province now constituting Britain, Northern France, and Western Germany by the abundance of certain characteristic species (those of the zone of *Ammonites Sowerbyi*), local depression took place within an area having a diameter of something like 90 miles, the amount of depression being greatest within its

* *Loc. cit.* p. 143.

centre. As a consequence of this local depression there was slowly accumulated by the growth of coral reefs, and the action of marine currents sweeping small shells and their fragments along the sea-bottom, a mass of calcareous strata, presenting many variations in its local characters, and constituting the formation to which we have applied the name of the Lincolnshire Oolite Limestone." Again, wherever the junction of the Upper and Lower Estuarine series can be examined there is proof of unconformity; and the thick series of beds of the Lincolnshire Oolite is wedged in between them in a lenticular manner; the zone of *Am. Murchisonæ* holding the ferruginous Northampton Sands (certainly at the base), the upper members possibly represent that of *Am. Sowerbyi.* Clearly this demonstrates that a great unconformity exists in the Midland area between the true Great Oolite series and the known top of the Lincolnshire Limestone. Those beds in the Cotteswold of Gloucestershire &c. containing *Ammonites Parkinsoni* and *Am. Humphriesianus,* or the Fuller's Earth, the Ragstones, and Upper Freestones of the Inferior Oolite of that region, are entirely wanting in Northamptonshire and Lincolnshire. This paucity of fossils belonging to those two zones is detected on examining the well-prepared lists of fossils by Mr. Sharp and Prof. Judd, and bears out the history of the deposits. No group more strikingly or certainly determines this than the Ammonites. Table XII. shows that a number of species are common to the Lincolnshire Oolite and the Great Oolite (133 out of 306), a greater number by far (40 species) than in the Lincolnshire and Yorkshire beds of the same age. This may be accounted for by the remarkable way in which the Lower Oolites of Yorkshire were deposited. On the other hand the relation of the Inferior Oolite of the south of England to the Lincolnshire Limestone is as 216 to 306, a very large number if we take into consideration the conditions of deposition and the extended development of the Southern Oolites. To make the Tables of greater value, I append another (XIII.) with the number of genera added; it will also keep up the uniformity of the series for reference.

TABLE XII.

	Geological Horizons.	Cotteswold Hills.	North-east Oxfordshire, and South Northamptonshire.	North Northamptonshire and South Lincolnshire.	South Yorkshire.
Middle Oolite	Oxfordian	Oxford Clay with Kellaways Rock at its base.	Oxford Clay	Oxford Clay, with Sandy beds representing Kellaways Rock at its base.	Sandy strata with Oxfordian fauna.
Great Oolite.........	Cornbrash	Cornbrash	Cornbrash	Cornbrash	absent.
	Great Oolite, Upper zone	Forest Marble and Bradford Clay.	absent	Thin argillaceous beds. Great Oolite Clays.	absent.
		Great Oolite Limestone	Great Oolite Limestone	Great Oolite Limestone.	
	Great Oolite, Lower zone	Great Oolite Limestone with Stonesfield Slate	Upper part of the Northampton Sand.	Upper Estuarine series.	absent.
Transition series	Fuller's earth	Upper and Lower Fuller's Earth with the Fuller's-earth rock.	absent	absent	absent.
Lower Oolite	Zone of *Ammo. Parkinsoni*	The Ragstone of the Inferior Oolite, including the Trigonia Grit, the Gryphite Grit, the Pholadomya Grit, and the Chemnitzia Grit.	absent	absent	absent.
	Zone of *Am. Humphresianus*	The Upper Freestone...	absent	absent	absent.
	Zone of *Am. Sowerbyi*	The Oolite Marl.........	absent	The Lincolnshire Oolite	Sands and Limestones of Cave &c.
	Zone of *Am. Murchisonæ*.................	The Lower Freestones of the Pea-grit	Lower portions of the Northampton Sand	The Northampton Sands	
Transition series	Midford Sand.........	Cephalopoda-beds and Sands.			
Lias	Zone of *Am. communis*	Upper Lias Clay	Upper Lias Clay	Upper Lias Clay	Upper Lias Clay.

Table XIII.—*Showing the Comparison between the Inferior Oolite of the Midland Counties and that of the S. of England and Yorkshire and the Great Oolite of the W. of England.*

	Inferior Oolite of the Midland counties.			Compared with		
	Lincolnshire Limestone.	Collyweston Slate.	Northampton Sand.	Inferior Oolite of the South of England.	Inferior Oolite of Yorkshire.	Great Oolite of the West of England.
Plantæ	$\frac{7}{6}$	$\frac{1}{1}$	$\frac{1}{1}$	...	$\frac{2}{2}$	$\frac{2}{2}$
Cœlenterata	$\frac{10}{21}$	...	$\frac{5}{7}$	$\frac{2}{17}$	$\frac{1}{1}$	$\frac{7}{9}$
Echinodermata	$\frac{13}{19}$	$\frac{1}{1}$	$\frac{10}{11}$	$\frac{12}{17}$	$\frac{5}{5}$	$\frac{7}{7}$
Annelida	$\frac{3}{8}$	...	$\frac{1}{3}$	$\frac{2}{6}$	$\frac{2}{5}$	
Crustacea	$\frac{1}{1}$	...	$\frac{1}{1}$			
Bryozoa	...	...	...	$\frac{1}{1}$	$\frac{1}{1}$	
Brachiopoda	$\frac{3}{26}$	$\frac{1}{1}$	$\frac{2}{24}$	$\frac{2}{18}$	...	$\frac{2}{3}$
{ Monomyaria	$\frac{14}{55}$	$\frac{11}{31}$	$\frac{14}{55}$	$\frac{11}{50}$	$\frac{9}{18}$	$\frac{13}{30}$
{ Dimyaria	$\frac{27}{101}$	$\frac{14}{32}$	$\frac{28}{90}$	$\frac{22}{63}$	$\frac{20}{42}$	$\frac{24}{54}$
Gasteropoda	$\frac{23}{56}$	$\frac{4}{5}$	$\frac{12}{29}$	$\frac{15}{33}$	$\frac{10}{15}$	$\frac{11}{27}$
Ammonites	$\frac{1}{4}$	...	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{1}$	
Belemnites	$\frac{1}{4}$	...	$\frac{1}{8}$	$\frac{1}{3}$	$\frac{1}{2}$	
Nautili	$\frac{1}{2}$	...	$\frac{1}{4}$	$\frac{1}{2}$		
Pisces	$\frac{2}{3}$	...	...	...	...	$\frac{1}{1}$
Reptilia	...	...	$\frac{2}{2}$			
	$\frac{106}{306}$	$\frac{32}{71}$	$\frac{79}{243}$	$\frac{66}{216}$	$\frac{52}{92}$	$\frac{67}{133}$

The four members or divisions of the Great Oolite of the Midland district are:—

1. The Upper Estuarine series.
2. The Great-Oolite Limestone.
3. The Great-Oolite Clays.
4. The Cornbrash (Limestone).

a. The Upper Estuarine is on the same horizon as the Stonesfield Slate.

b. The Great-Oolite Limestone is an extension of the calcareous group of the south.

c. The Great-Oolite Clays represent the Forest Marble and Bradford Clay.

d. The Cornbrash is the same distinct stratum known all through England.

These four divisions demand from the palæontologist careful analysis. The Limestones are eminently characterized by their

special faunas. Everywhere in this area *Ostrea Marshii*, *Echinobrissus clunicularis*, *Avicula echinata*, *Gervillia aviculoides*, *Terebratula obovata*, *T. ornithocephala*, *Ammonites macrocephalus*, *A. Herveyi*, and *A. discus* characterize the Cornbrash. The Great-Oolite forms are equally distinct and important—*Ostrea Sowerbyi*, *O. subrugulosa*, *Clypeus Mülleri*, *Terebratula maxillata*, *Rhynchonella concinna*, *Homomya gibbosa*, *Nautilus Baberi*, *N. hexagonus*, and *N. subtruncatus* being in this group the dominant forms.

Upper Estuarine Series.—Nothing in the south and south-west of England resembles these beds: they show an alternation of marine and freshwater conditions, such as would now take place under elevation or depression in the estuaries of rivers; but few fossils accompany these clays and sands; they cover but small areas, and often occur in pipes let down into the underlying strata *. We are indebted to Prof. Morris † for first determining the estuarine character of the beds above the Lincolnshire Limestone. Morris identified *Cyrena* (*C. Cunninghami*), *Unio*, and *Paludina*.

Great-Oolite Limestone.—The upper zone of the Great Oolite, here as elsewhere in England, is remarkably uniform in character in its range from Gloucestershire to Mid-Lincolnshire; in the latter area it thins out, and finally disappears before reaching the Humber. A considerable proportion of the species also occur in the Cornbrash, no less than 119 species uniting the Cornbrash proper with the Great Oolite of the Midland district. The chief fossil localities noticed in the Rutland memoir are of necessity those in which the type forms exist; the present agreement of the species from each locality is a coincidence not to be overlooked; and it will be seen, on consulting Table XIV., that only the Lamellibranchiata form a large and characteristic fauna. All the other groups are represented by one, two, or three species each; throughout the whole of the 10 localities (5 Great Oolite and 5 Cornbrash), only a single Coral, *Anabacia orbulites*, seems to have been recorded in any Great-Oolite or Cornbrash locality; with the exception of Rushden, none of the localities have yielded any. The Echinodermata found in the Great Oolite are only *Echinobrissus clunicularis*, *E. sinuatus*, and *Pygaster semisulcatus*; no Crustacea, Bryozoa, Ammonites, or Belemnites have been recorded, and only one *Nautilus* (*N. Baberi*). On the other hand the Bivalve Molluscan fauna is large. The five Great-Oolite areas yield a recurrent fauna of 75 genera, or a mean of 15 for each locality; the species 190, or 40 for each of the five localities. This shows that the species have not been rigorously searched for. We may say that the Gasteropoda are hardly represented; for we know of only 5 species, *Natica neritoidea*, *N. globosa*, *Nerinæa funiculus*, *N. Voltzii*, and a *Monodonta*, for the whole 5 localities. The Brachiopoda are individually numerous, but the species few: the two genera are *Terebratula* and *Rhynchonella*; 8 species are all that have occurred in both genera.

* See the clear description of these beds in Prof. Judd's memoir, *loc. cit.* pp. 188–200, with reference to sheet 64 of the Geological-Survey map.

† Quart. Journ. Geol. Soc. vol. ix. p. 338.

TABLE XIV.

		Great Oolite.					Cornbrash.					
		Oundle.	Benesfield.	Ailsworth.	Belmesthorpe.	Daneshill.	Rushden.	Oundle.	Manthorp.	Bourn.	Stilton.	Yorkshire.
		1	2	3	4	5	6	7	8	9	10	
	Plantæ	...	...	...	...	...	1/1					
	Protozoa	...	...	...	...	...	...	...	...	...	...	1/2
	Actinozoa	...	...	...	...	...	1/1	...	...	...	...	2/2
	Echinodermata	1/2	2/2	1/1	...	1/1	1/1	2/2	...	1/1	3/4	4/5
	Annelida	...	...	1/1	...	1/1	...	...	1/1	1/1	1/3	1/3
	Crustacea	...	...	...	...	...	1/1	...	...	...	1/1	1/2
	Insecta											
	Bryozoa	...	...	...	...	...	4/4	...	...	...	...	2/3
	Brachiopoda	2/4	...	2/5	1/1	2/2	2/7	2/6	2/4	2/2	2/12	3/5
Bivalvia.	Monomyaria	3/3	4/9	4/4	6/8	6/8	6/16	5/12	7/9	4/7	5/16	12/28
Bivalvia.	Dimyaria	11/15	6/6	14/20	9/13	12/18	14/27	6/11	4/4	7/8	10/21	25/62
	Gasteropoda	2/2	...	3/4	1/1	...	3/3	...	...	...	1/1	14/18
Cephalopoda.	Ammonites	...	...	...	...	...	...	1/1	1/1	1/2	1/3	1/1
Cephalopoda.	Belemnites	...	...	...	...	...	...	...	...	...	...	1/1
Cephalopoda.	Nautili	1/1	...	...	1/1	...	1/1	...	...	1/1	...	1/1
	Pisces	...	1/1	1/1	1/1	...	1/1	...	...	...	3/4	
	Reptilia	...	...	...	...	...	1/1	...	...	1/1	3/3	2/2
	Mammalia											
		20/27	13/18	26/36	19/25	22/30	36/64	16/32	15/19	18/23	30/68	70/135

Comparison between the Great Oolite and Cornbrash of Northamptonshire is given in the above Table. The last column for Yorkshire is added for comparison, and will show how much richer the Northern Cornbrash than that of Northamptonshire &c.

The absence of corals may account for the non-oolitic character of the Great-Oolite Limestones, a marked feature throughout the series under notice.

CORNBRASH.—It is doubtful whether the Cornbrash of Yorkshire is on precisely the same horizon as that of Lincolnshire and Northamptonshire. It retains its general and uniform limestone character from Dorsetshire and Gloucestershire, and disappears under this condition before reaching the Humber. At Brigg it is hardly distinguishable from the thin overlying Kellaways Rock, both horizons not being 5 feet thick. Prof. Phillips fully notices the

Cornbrash fauna in Oxfordshire, naming 74 species—and associated with it 153 Great-Oolite species from the Oxford area, 50 of which are also Cornbrash and mostly from Islip. The fauna distributed through the Cornbrash of five chief localities noticed in the Rutland memoir is most variable (Midland Oolites). It numbers 30 genera and 68 species at Stilton, 36 genera and 64 species at Rushden, 16 genera and 32 species at Oundle, 18 genera and 23 species at Bourn, and 15 genera and 19 species at Manthorp. The Yorkshire type is far more prolific. Leckenby, in his paper on the Cornbrash of Yorkshire, enumerates no less than 70 genera and 135 species. As everywhere else, the Cephalopoda are reduced to a minimum, only 1 species of Ammonite (*A. Herveyi*), 1 Belemnite (*B. tornatilis*), and 1 Nautilus (*N. hexagonus*) being known. The Oxford deposit shows the same fact. Table XIV. shows the fauna of the two horizons for the Midland districts; Yorkshire is added for comparison here, and may induce research into the causes which led to its great development, change of character, and greatly increased fauna N. of the Humber, and the sudden change from the sandy Upper Estuarine and plant-bearing beds to a calcareous zone about 5 feet thick with so rich a fauna.

The late sub-Wealden exploration has done much for our knowledge of the Upper Jurassic rocks of Britain; it has especially altered our views as to the nature, subdivision, and thickness of the Kimmeridge Clay of England.

In 1875, the Rev. J. F. Blake, M.A., read before our Society his paper "On the Kimmeridge Clay of England." Since the memorable memoir of Dr. Fitton on the strata below the Chalk, nothing seems to have been done with the beds of the Oolitic group immediately above the Corallian beds. Damon, in his 'Guide to the Weymouth District,' devotes some space to this member of the Upper Oolite; and the late sub-Wealden exploration did much towards adding to our knowledge of the thickness and fossil contents of the Kimmeridge beds of Sussex below the Wealden series. On the continent close study and analysis has resulted in separating the Kimmeridge-clay group into 3 zones:—the lowest, that of *Astarte supracorallina*, or the Astartian zone; the second or middle, that of *Pterocera Oceani*, or the Pterocerian zone; the third or upper is either referred to or included in the zone of *Trigonia gibbosa*, in the Portland strata, or separated as the zone of *Exogyra virgula*, or the Virgulian zone. The names Astartian and Pterocerian have much significance, as bearing upon the correlation with the same beds of the continent—not that we must lay too much stress upon a few or certain species as definitely fixing the horizons of two areas widely separated.

In the Kimmeridge Clay this is to be observed and borne in mind. Although, broadly speaking, certain portions are recognized and separated by their general and, at times, special assemblage of fossils, yet many that are in one locality and portion highly cha-

racteristic, are absent in that portion in another, and may characterize instead either a higher or lower zone.

Thus, as stated by the author, the well-known "*Exogyra virgula* in the Jura bernois and elsewhere is characteristic of the upper portion; at the Cap de la Hève [Dept. Seine-Inf., N.W. of Havre] it occurs throughout; and in England it is wanting only in the upper part, or sometimes, as in Lincolnshire, appears to be absent entirely." So, again, the still better-known or more conspicuous "*Rhynchonella inconstans*, which is the characteristic species of the lowest beds in England, in the environs of Montbéliard is found in all but the lowest, and most frequently at the top, and has not been met with in the sub-Wealden boring," although it was believed, through other fossils, that we were near the base. Mr. Blake therefore suggests that "on account of this peculiarity of the distribution of the Kimmeridgian fossils, it is better to use the more general terms Lower, Middle, and Upper."

The chief object of Mr. Blake's paper is to show into what palæontological and lithological subdivisions the Kimmeridge Clay may be naturally separated through a study of its features in the field. Mr. Blake shows that there are only two divisions or sets of beds which are sufficiently distinct to justify their separation under different titles. The upper division, "Virgulian," agrees with that of Dr. Waagen; but our lower includes his middle region and part of his lower; "while the remaining part of his lower region, and possibly part of his zone of *Cidaris florigemma*, constitute a series of beds which, from their containing as much of a Corallian as a Kimmeridgian fauna," Mr. Blake designates the "Kimmeridge Passage-beds" (*loc. cit.* p. 197).

Mr. Blake's paper therefore embraces the history of the Kimmeridge Clay through three divisions—

1. The Upper Kimmeridge,
2. The Lower Kimmeridge, and
3. The Kimmeridge Passage-beds.

The Upper Kimmeridge Clay (Virgulien of foreign authors) differs essentially both lithologically and palæontologically from the zones below. This division is developed in Lincolnshire and Dorsetshire; and in it exclusively occur the bituminous shales, paper shales, and cement stones. These beds contain but few species, but an infinity of individuals. Compressed Ammonites, *Discina latissima* and *Lucina minuscula*, cover the leaf-like planes of deposition. Mr. Blake appends a complete and measured section of the thickness of the Kimmeridge-clay beds at Kimmeridge Bay, where they are exhibited to the extent of 650 feet, probably the maximum in any exposed section. *Cardium striatulum*, *Discina latissima*, and *Lucina minuscula* occur throughout; *Exogyra virgula* occurs near the base of the upper shales; *Ammonites biplex*, *Astarte lineata*, *Pecten lens*, *Avicula vellicata*, *Belemnites Sowichii*, and *Lingula ovalis* occur in the upper 240 or 250 feet. Near the base of the Upper Kimmeridge

we also find *Am. biplex*, *Am. Thurmanni*, *Astarte lineata*, and *Arca rhomboidalis*. In Wiltshire, Oxfordshire, and Buckinghamshire the Upper Kimmeridge appears to be very thin. At Swindon and Hartwell there is little room for it between the Lower Kimmeridge and the Portland Sand. The great pit at Ely shows but little Upper Kimmeridge in vertical thickness; and, as in Lincolnshire, the chief fossils are *Discina latissima*, *Cardium striatulum*, and *Lucina minuscula*. *Am. serratus* and the abundance of *Exogyra virgula* mark the commencement of the Lower Kimmeridge, or the passage from the Upper to the Lower.

Mr. Blake has prepared a sketch map showing the geographical position of various pits in the Kimmeridge Clay of Lincolnshire, ranging from Ferriby in the north, to Horncastle and Spilsby in the south. Numerous fossils occur, some 15 species having been collected by Mr. Blake. Prof. Judd records the Kimmeridge Clay at Filey Bay, where it is exposed at certain times below the ordinary low-water mark. Mr. Leckenby also has collected Ammonites from Filey Bay; but the fauna, small as it is, possesses quite a facies of its own. Mr. Judd records the following species from the Upper Kimmeridge of Filey Bay—*Ammonites biplex*, several species of the group Planulati, *Ostrea*, sp., *Inoceramus*, sp., *Cardium*, sp., many bivalves, *Discina latissima*, *Lingula ovalis*, Ichthyosaurian vertebræ (Quart. Journ. Geol. Soc. vol. xxiv. p. 239). The Upper Kimmeridge fauna numbers 21 species; 14 are peculiar, and 7 are common to lower and higher beds.

The Lower Kimmeridge.—Mr. Blake does not admit the Middle Kimmeridge division of Waagen for England, although granting that the deposition of the beds may have been continuous and some of them contemporaneous with the Middle period. The special fauna of the Middle series abounds in Gasteropoda of the genera *Pterocera*, *Nerinæa*, *Natica*, and *Chemnitzia*, together with many varieties of *Panopæa* and *Pholadomya*. "Only the discovery of such a fauna," says Mr. Blake, "would justify the recognition of Middle Kimmeridge beds" (*loc. cit.* pp. 204, 205). Prof. Judd, however, following Waagen, has enumerated about 24 species as coming from the Middle Kimmeridge of Filey Bay, viz. 2 Belemnites, 7 Ammonites, *A. biplex*, *A. mutabilis*, *A. triplicatus*, *A. Marantianus*, *A. yo*, *A. Berryeri*, and *A.* sp., *Exogyra virgula*, *E. nana*, and 9 genera and species of Bivalves, *Rhynchonella*, &c. From the Lower Kimmeridge of Speeton Prof. Judd obtained only *Am. alternans* and *Rhynchonella inconstans* (Quart. Journ. Geol. Soc. vol. xxiv. p. 240).

The Lower Kimmeridge is best studied in Lincolnshire, where it agrees with the Dorsetshire type. At Horncastle 17 species have been collected, all of which elsewhere in Lincolnshire are associated with *Am. serratus*. The peculiar fossils here are *Rostellaria mosensis*, *Cerithium crebrum*, *Astarte supracorallina*, *Avicula œdilignensis*, *Pecten Grenieri*, *Corbula Deshayesia*, &c. East of Brigg and the Wrawby cutting I obtained many of the species named by Mr. Blake. The Market-Rasen pits yield a large fauna; no less than 46 species have been obtained from them, representing 31 genera.

Reptilia	2	genera and	2	species.
Ammonites	1	"	6	"
Belemnites	1	"	1	"
Gasteropoda	6	"	8	"
Dimyaria	12	"	16	"
Monomyaria	6	"	10	"
Brachiopoda	2	"	2	"
Crustacea	1	"	1	"
	31		46	

Comparing the Lower Kimmeridge of other counties with this typical development in Lincolnshire, Mr. Blake includes also the whole of the Middle Kimmeridge of Filey Bay in this Lower division. He regards the base of the Ely pit as Lower Kimmeridge on account of its contained fossils, such as *Am. serratus*, *A. longispinus*, *Arca rhomboidalis*, *Astarte ovata*, *Serpula tetragona*, *Avicula œdilignensis*, *Pecten Grenieri*, and *Lingula ovalis*. Mr. Blake also adds a list of 16 genera and 21 species which occur in the Kimmeridge Clay of Swindon. This is the first time any notice has been given of Kimmeridge-clay fossils from that locality; and so with Wootton Bassett: the Lower beds there yield 13 species, all Swindon forms. Near Weymouth the dark clays have yielded 33 species—Reptilia 1 species, Pisces 2 genera and 2 species, Ammonites 3 species, Gasteropoda 4 genera and 5 species, Dimyaria 11 genera and 14 species, Monomyaria 6 genera and 6 species, Brachiopoda 2 genera and 2 species.

The Passage-beds of Blake have their type-locality at Weymouth, and are sandy stratified beds extremely rich in fossils. They appear to be, according to Dr. Waagen, the equivalent in part of Dollfus's "Calcaires à trigonies" of the Cap de la Hêve; they are the Kimmeridge Grit of Damon; Waagen also includes part of them in the Upper Calcareous Grit.

Mr. Blake finds *no indication of such beds* where the Coral Rag is absent, as in Lincolnshire; but in the presence of that formation they are everywhere developed. This would incline Mr. Blake to attach them to the Coral Rag rather than to the Kimmeridge Clay.

The Sandsfoot-Castle section near Weymouth has yielded 44 genera and 63 species from two thin beds; a few supplemental forms bring the list up to 72 species: 29 are peculiar; 13 are common to it and the Coral Rag; and 20 pass up into the Kimmeridge Clay—10 appearing from lower beds, including probably some of the peculiar forms. The same conditions, both lithological and palæontological, are repeated at Osmington Mills and Ringstead Bay.

Mr. Blake, in concluding his able paper, recapitulates the main points at which he had arrived; and of that summary the following is an abridgment:—

1. The Kimmeridge Clay in England is divisible into two sections, Upper and Lower, and, when preceded by the Coral Rag, possesses at the base the Kimmeridge Passage-beds.

2. The Upper Kimmeridge is comparable to the lower portion of the Virgulian group of foreign authors.
3. All the great Saurian remains from near Kimmeridge belong to this portion of the series; the Paper-shales, Paper-slabs, bituminous shales, and cement-stones reach a thickness of 650 feet.
4. No distinct fauna, comparable to that of the Middle-Kimmeridge or Pterocerian group, has yet been discovered in England, though several of the less peculiar fossils of that group are found associated with Lower-Kimmeridge forms.
5. The Lower Kimmeridge is a mass of blue or sandy clay very little stratified, with numerous calcareous doggers. It is largely developed in Lincolnshire, where it shows well-marked regions, which exhibit, however, such a gradual community of fossils that they cannot be made the basis of subdivision, but must be considered local features. The whole represents the Astartian group of foreign geologists.
6. The fauna of this section will be found to have been considerably added to.
7. The Kimmeridge Passage-beds are developed only in the presence of the Coral Rag, whose fossils ascend into them, but not to any appreciable extent above.
8. They are typically developed at Weymouth, where they are about 20 feet thick.

In January 1877, the Rev. J. F. Blake, M.A., F.G.S., and W. H. Hudleston, Esq., M.A., F.G.S., laid before the Society their paper "On the Corallian Rocks of England"*. Probably no more important paper had yet appeared upon the upper part of the Middle Jurassic rocks of England, exhaustively written, ably argued, and eminently practical. No less than five districts are described in every possible detail, viz.:—1. The Weymouth district; 2. The North Dorset district; 3. The North Wiltshire, Berkshire, and Oxfordshire range; 4. The Cambridge reef; and 5. The Yorkshire basin, this last embracing four subdistricts or areas.

The authors show that the strata from the Oxford Clay to the Kimmeridge Clay were one continuous deposit, which, physically considered, has been termed a "great pelolithic formation" quietly laid down slowly or quickly in the areas named, subject to alterations in the physical conditions, which changed the character of the deposits. That these changes are local is proved by the discontinuity and variable nature of the deposits, showing also that they were not all contemporaneous, or indicative of a period termed Corallian, "for all or any of the coral deposits that have been formed between the commencement of the Oxfordian and the close of the Kimmeridgian epoch."

The "Coral Rag" of England, as these rocks were *originally designated* by William Smith from their development as such in the area studied by him, have now, through minute and careful re-

* Quart. Journ. Geol. Soc. 1877, vol. xxxiii. pp. 260–405.

search, been divided into Upper Calcareous Grit, Coralline Oolite, and Lower Calcareous Grit, as developed in Yorkshire; we must not assume, however, that rocks of "similar lithological character are the equivalents of each other in different localities."

The influence that physical conditions have upon the contained fauna has been much overlooked by palæontologists. The resemblance, if not identity, of many Corallian species with those belonging to the Great or the Inferior Oolite proves that much of the peculiarity of the Corallian fauna is due, not to the lapse of time, but to the conditions of deposition or the persistence of certain physical features favourable to the continuity of that life which commenced in an earlier stage. "Nevertheless Palæontology does not fail us as a guide, and there are still a sufficiency of forms, above the influence of physical conditions, which indicate satisfactorily by their association the relative age of the deposits"*. The authors endeavour, through the physical conditions under which each deposit was formed, to estimate the contained fauna at its true chronological value, not, however, omitting the history of the beds containing them.

The areas studied and described in the paper are of unequal magnitude, as would be expected; and Messrs. Blake and Hudleston state that in the description of these five areas their endeavour was to study the development, physical conditions, and correlations of the Corallian beds, and not their pure stratigraphy.

The Weymouth district affords three distinct opportunities for studying the Corallian beds—the neighbourhood of Weymouth, on the east at Osmington, and on the west near Abbotsbury. The authors employ local names to designate their horizons; and from the Calcareous Grit ("Nothe Grits" of the Weymouth area) they enumerate 23 species—2 Cephalopoda, 3 Gasteropoda, 15 Lamellibranchs, 2 Annelids, and 1 Crinoid (a few species here ally the Oxfordian with the Corallian group); other (6) species occur to increase the fauna to about 30.

The succeeding "Nothe Clays" have yielded 16 species, 12 of which are bivalves, still having an Oxfordian facies. The "Bencliff Grits" east of Sandsfoot Castle, 20 feet thick, contain few fossils, *Gervillia aviculoides*, *Exogyra nana*, and *Trigonia corallina* being most characteristic.

The Marls and Oolites of Osmington ("Osmington Oolite") contain 17 species—12 bivalves, 4 Gasteropoda, and the well-known *Echinobrissus scutatus*.

The Trigonia beds (Coral-Rag beds) of Weymouth and Osmington named in the paper number 70 species—2 species of Ammonites, 17 Gasteropoda, 43 Lamellibranchs, 5 Echinodermata, and 3 Actinozoa: 8 other species are added from another locality (thus increasing the fauna to 78); 5 of these are bivalves, 2 Echini, and *Ammonites plicatilis*.

The Sandsfoot-Castle beds (the "Kimmeridge Passage-beds") show that their fossil contents were entombed on the actual spot

* *Vide* Introduction to Messrs. Blake and Hudleston's paper, *loc. cit.*

"where sponges luxuriated," and were accompanied by "the great *Lima pectiniformis.*" The authors found in these beds no less than 34 species, 23 of which were Lamellibranchs, with the 2 characteristic Brachiopoda, *Discina Humphriesiana* and *Lingula ovalis*, accompanied by *Cidaris florigemma*, *C. Smithii*, and *Echinobrissus scutatus*. Only 2 species of Gasteropoda occurred—*Pleurotomaria Münsteri* and *Littorina pulcherrima*.

The great deposit of the Abbotsbury Ironstone (hydrated ferric oxide), containing especially *Rhynchonella corallina* and *Waldheimia lampas*, yielded to the authors 30 species, the 5 Brachiopoda indicating Kimmeridgian affinities, or a close approach to that horizon. Messrs. Blake and Hudleston truly say that there is nothing specially "coralline" in the rocks of the Weymouth area as connected with corals; and the term 'Coral Rag,' which is an essentially lithological name, is here especially inappropriate. Only in one limited area does such a rock occur in the whole district.

The authors next discuss the Corallian rocks of the North-Dorset area. The Great Sturminster railway-section afforded the key to the whole district*. The sections at Gillingham, Cucklington, Todbere, and Langham all show how little calcareous grit occurs among the more argillaceous series of this region: and the absence of *Cidaris florigemma* is significant; it has never occurred in the rubbly limestones of the Sturminster section. About 40 species have been determined from the sections above named.

Next in importance is the long and narrow exposure in North Wiltshire, Berkshire, and Oxfordshire; the rocks occur in many small areas, and have distinctive characters.

The Westbury Corallian beds consist chiefly of the iron-ore and its associated fossils, which are few. 11 species are enumerated in the authors' paper, most of which I have also obtained at the extensive excavations. The Steeple-Ashton beds may be on the upper horizon of the Oxfordian group; 18 species are named, 14 of which are Lamellibranchiata.

From the well-known Calne district Messrs. Blake and Hudleston obtained a large fauna; the *Cidaris-florigemma* Rag contained, at Hilmarton, 28 species.

The Coralline Oolite and Calc Grit of Highworth contain a fine assemblage of fossils (37 species). The Corallian rocks in the neighbourhood of Faringdon, and at Marcham, Cumnor, Headington, and Wheatley are described, and the special faunas of these localities are given by the authors. The most singular exposure of the Corallian Rocks occurs at Upware, between Cambridge and Ely. These beds are probably the highest in the Corallian series; on them lie the phosphatic nodules and sands of the Neocomian beds. The corals and other fossils undoubtedly prove this Upware exposure to be "Coral Rag." It is peculiar in its lithological characters; and the irregularity of the bedding is indicative of its "reef-like character," to which condition, and not entirely to denudation, Messrs. Hudleston and Blake attribute its termination. No Ammonites have yet oc-

* *Loc. cit.* p. 276, for section and description.

curred; 6 species of Gasteropoda, *Chemnitzia heddingtonensis* and *Cerithium muricatum* being amongst the number; 15 genera and 21 species of Lamellibranchiata; *Cidaris florigemma*, the only species illustrating the Echinoidea; with 4 typical Corals, *Thamnastræa*, *Isastræa*, *Montlivaltia*, and *Rhabdophyllia*. There is no indication of the Lower Calcareous Grit.

THE YORKSHIRE BASIN.

130 miles north of Upware the Coral Rag of Yorkshire makes its southernmost appearance.

The authors subdivide the Yorkshire Corallian area into four districts—(1) the Scarborough, (2) the Pickering, (3) the Hambleton, and (4) the Howardian districts.

The *Scarborough district* is most ably described by the authors, both in this communication and by one of them (Mr. Hudleston) in a paper read before the Geologists' Association (vol. iv. p. 353 *et seqq.*). The fine section at Filey, a little to the north of the Brig, exposes the Upper Calcareous series and the Filey-Brig Calc-grit, the Lower Calcareous series, and the Lower Calcareous Grit proper. The first is in two divisions, and about 13 feet in thickness: the upper (No. 1) contains few fossils; from the second (No. 2) 23 species were obtained—

Ammonites	4	species.
Gasteropoda	4	,,
Lamellibranchiata	15	,,
	23	

The Ammonites are all characteristic, *A. cordatus* and *A. perarmatus* being the chief forms; they are associated with *Chemnitzia heddingtonensis*, *Littorina muricata*, *Gervillia aviculoides* large and abundant, and *Pholadomya decemcostata*. The Filey-Brig Calc-Grit is 10 feet thick, and composed of massive yellow calcareous grit, characterized by a large *Ostrea*, var. of *O. bullata*.

The Lower Calcareous series is divided into two groups, the upper 15 feet, the lower 11 feet thick. 25 species occur in the lower group. No Gasteropoda seem to occur here; but there are 10 Lamellibranchiata, 4 Brachiopoda (the characteristic *Rhynchonella Thurmanni* being abundant, and 6 species of other groups, with *Waldheimia Hudlestoni* and *W. bucculenta*), and 5 genera and 5 species of Echinodermata.

The Lower Calcareous Grit proper is about 60 feet in thickness, and occupies the base of the section. The soft calcareous sands contain huge ball-stones with nests of fossils. *Trigonia triquetra*, *Pinna lanceolata*, *Ostrea solitaria*, &c. occur in the upper division. The lowest part of this Lower Calc-grit is rich in fossils—*Ammonites perarmatus*, *A. cordatus*, *Perna quadrata*, and *Astropecten rectus*; below is the Oxford Clay (*loc. cit.* pp. 315–319).

The authors carefully describe the Corallian series in the interior of the country, illustrating, through the gorge of the Derwent at the Forge valley, a complete section of the whole Corallian series from

the Upper Limestones to the top of the Lower Calcareous Grit, a thickness of 136 feet. This Forge-valley section is more complete than those exposed on the coast. The characteristic fossils *Cylindrites elongatus*, *Gervillia aviculoides*, and *Rhynchonella Thurmanni* occur in the White Quarry or upper portion of the Lower Limestones. The authors correlate the Oolites of Scarborough Castle Hill with the Lower Oolite of the Forge-valley section, the fossil remains confirming this. The Seamer district (Seamer, Ayton, and Brompton) have yielded a large fauna: 38 species, 14 univalves, 19 bivalves, 3 Echinoidea, and 2 Corals are catalogued; but the Crossgates quarry yields others, these being the most characteristic. The remarkable outlier at Hackness, which exhibits the whole Corallian system resting on the Oxford Clay which passes down into the Kellaways Rock, is described. The following series occurs in "Silpho Heights:"—

Upper Limestones.	1. Upper Calcareous Grit.
	2. Upper or true Coral Rag.
	3. Coralline Limestone (Bell-Heads Limestone).
	4. Gritty limestone and sandy beds (Middle Calcareous Grit).
Lower Limestones.	5. Lower Oolite series.
	6. Lower Coral Rag.
	7. Basement or Passage-beds. (In all about 80 feet.)

These beds are separately described, and their fossil contents given for the chief forms (about 30 species).

The Pickering District.

This classical area receives most careful attention, and is exhaustively treated. A complete section of all the Corallian beds is seen in the gorge of Newtondale, at the outlet of which lies Pickering. The upper portion is, as the authors say, magnificently displayed in the numerous quarries near the town. The succession is as follows in the deep gorge of Newtondale:—

	feet.
Supracoralline beds	20
Upper Limestones	50
Trigonia beds and Middle Calcareous Grit	45
Lower Limestones	60
Ditto, including basement or Passage-beds	30
Lower Calcareous Grit (say)	100
	305

A generalized section of the Pickering beds is given on p. 335, and also a detailed description of the Upper, Middle, and Lower divisions, or the *Supracoralline beds*, *Upper Limestones*, and the *Shell-beds and grits* (Middle Calcareous Grit in part). The most richly fossiliferous of all the divisions is that of the Shell-beds and grits (Middle Calcareous Grit); nearly all the fossils in collections marked Pickering are from this horizon. 36 species were obtained by the authors from the three *Trigonia*-beds in this lower group. *Trigonia perlata*, *T. Meriani*, *Chemnitzia heddingtonensis*, *Littorina muricata*, *Cerithium muricatum*, *Gervillia aviculoides*, *Cucullæa corallina*, *Avi-*

cula ovalis, *Cidaris Smithii*, *Echinobrissus scutatus*, &c., are amongst the forms that abound. The fossils collected from the Upper Calcareous Grit of Pickering number 26 species, 19 of which are bivalves. Details are given on p. 347 of the fine section at Sinnington in the Upper Limestones of the middle division of Pickering (*loc. cit.* pp. 333–340).

The Hambleton District.

This extensive area is now clearly understood through the researches of Messrs. Blake and Hudleston. They describe five horizons or subformations, tracing them over a distance of eight miles, namely :—

1. Lower Calcareous Grit,
2. Hambleton Oolite,
3. Middle Calcareous Grit, Corallian.
4. Coralline Oolite,
5. Upper Calcareous Grit,

Kimmeridge Clay.

The characteristic fossils are given in the description of the five horizons ; neither time or space will allow me to follow the authors through their careful analysis of the physical structure of the county or their deductions from the organic remains. The fossils from the Coral Rag, the Calcareous Grits, and Coralline Oolites are given from several quarries and cuttings of Oswaldkirk Hagg, Ampleforth Beacon, Nunnington, and Canklass End ; about 30 species have occurred to Messrs. Blake and Hudleston in their researches through the Corallian beds of the Hambleton district.

The Howardian Hills.

This fourth district in the Yorkshire Corallian area embraces the inner portion of the range of hills which bounds the Vale of Pickering to the S.W. The authors here base the sequence of their stratigraphical succession chiefly on palæontological grounds, owing to the more complicated nature of the rocks than in the "more massive tabular range" to the north and north-east. Less attention is paid by them to the petrological condition of the groups, on account of this more complex nature of the area.

The authors divide the Howardian area into two districts, one west of the Derwent, the other east of that river. Commencing with the "Lower Calcareous Grit and Passage-beds" west of the Derwent, and in the Park quarry, Castle Howard, the presence of *Ammonites perarmatus* shows their position to be low down in the Lower Calcareous Grit. *Am. cordatus* and *Am. vertebralis* also occur in these beds ; it is the horizon of the large *Aptychi* and phragmocones of large Belemnites (*B. abbreviatus*). The Passage-beds (Middle Grits and Lower Limestones of Mr. Fox Strangways) between the Lower Calcareous Grit and Coralline Oolite, containing the large *Trigonia Meriani*, *Pholadomyæ*, and *Pecten intextus*, here receive notice. The Coralline Oolite and Coral Rag of Malton are most carefully analyzed, the former, in its lower division, holding the well-

known *Chemnitzia*-beds (*C. heddingtonensis*) with *Nerinæa Goodhalli*, *Phasianella striata*, *Cerithium muricatum*, *Lima læviuscula*, &c. It is from the upper part of this division (the Coralline Oolite) that the new and remarkable Araucarian fruit (cone), *Araucarites Hudlestoni*, Carr., was obtained. Mr. Carruthers, F.R.S., to whom this cone was submitted, places it in the section *Colymbea* of the genus *Araucaria*, now represented in South America, Australia, and New Caledonia. The Inferior-Oolite form (*A. sphærocarpus*) and the Wealden one (*A. pippingfordensis*) belong to the same section of the genus. (*Vide* Carruthers, Quart. Journ. Geol. Soc. vol. xxxiii. p. 402, appendix to Messrs. Blake and Hudleston's paper.)

No less than 70 species are named by the authors in the list of fossils from the Coralline Oolite of Malton, omitting those species occurring in the Coral Rag proper. Very few forms are common to the Coralline Oolite and the true Coral Rag above; out of the 70 named not more than 10 occur to connect the two horizons. The Coral Rag proper, which overlies the Coralline Oolite, is essentially characterized by *Cidaris florigemma*, *Glypticus hieroglyphicus*, *Pseudodiadema hemisphæricum*, *Thecosmiliæ*, *Rhabdophylliæ*, &c. About 50 species range through the Coral Rag series of the Howardian beds west of the Derwent.

East of the Derwent.—This division occupies the high land of Langton Wold, at the southern ridge of which the Howardians are buried beneath the Chalk. Messrs. Blake and Hudleston state with truth that "there is no such display of Coral Rag elsewhere in England as at North-Grimston Hill, where "the Coral Rag may be said to culminate both as to variety and thickness of development, and also in the richness of its fossil contents" (*loc. cit.* p. 374). The authors give details of the Grimston-Hill section from the base with Lower Calcareous Grit, through the Coralline Oolite and Passage-beds, the Coral Rag, and Supracoralline series (*vide* described and drawn section, pp. 374–381). The Mamillated-Urchin series (in the Coral Rag), containing *Echinobrissus scutatus*, *Pseudodiadema hemisphæricum*, *Cidaris florigemma*, *C. Smithii*, *Hemicidaris intermedia*, *Collyrites bicordatus*, *Pygaster umbrella*, &c. &c., receives careful stratigraphical determination. The geographical position of these Urchin-beds would appear to be restricted along the southern margin of the formation, where lithologically the beds are highly argillaceous and fine-grained. The North-Grimston Limestone (Coral Rag proper) and its splendid group of fossils are minutely described; and Messrs. Blake and Hudleston append a remarkable list of the Langton-Grimston-Rag or Upper-Corallian fossils, in which are enumerated 70 species: 20 of these are Gasteropoda, 34 Lamellibranchs, 6 Cephalopoda, 7 Echinoidea, &c. Few corals are given, *Thecosmilia* and *Rhabdophyllia* are the most frequent.

The authors then summarize the work done by them. The Weymouth area is epitomized in ascending order, the Nothe Grits (characterized by *Perna quadrata* and *Pecten fibrosus*) being at the base. Clays (the "Nothe Clays") separate the above from an upper grit (the "Bencliff Grit") having at its base huge doggers; these two

divisions form the Lower Calcareous Grit. The succeeding series consist of Oolites and Marls, which include the "Osmington Oolite" or the "*Trigonia*-beds," with *T. clavellata* and *Cidaris florigemma*. Above the main limestones at Weymouth succeeds 40 feet of clay (the "Sandsfoot Clay") overlain by ferruginous sands and grits with large spongious growths, containing *Lima pectiniformis*, *Cidaris florigemma*, *Lingula ovalis*, *Littorina muricata*, and *Astarte supracorallina*. These are well shown at Abbotsbury. A peculiar Upper Coral Rag is developed above these grits at Ringstead Bay and below the Kimmeridge Passage-beds. The Abbotsbury Ironstone is upon a higher horizon. No true Coral-reef occurs within this area; but the changes in the character of the deposits, on the whole thick, are exceptionally numerous.

North Dorset.—The Corallian series varies considerably in this area, the Lower Calcareous Grit being scarcely represented in the southern part—Marls, and Pisolites replacing the Grits, much false-bedding succeeding these. In the northern portion the Lower Calcareous Grit is well developed, especially near Cucklington and Gillingham, where they gradually merge into the Oxford Clay. The Limestones also prevail, but are impure in character; at Mappowder and Marnhull the false-bedded series are economically used, being burnt for lime.

Wiltshire and Oxfordshire Range.—The Lower Calcareous Grit is the most constant member of the many types that occur in this long belt of deposits; the iron-ore beds at Westbury in the southern part, like those of Abbotsbury, occupy the extreme top of the series. At Steeple-Ashton and Calne the Lower Calcareous Grit is well developed; the chief feature at Calne is the non-development of any beds but those containing *Cidaris florigemma*.

At Highworth the chief feature is the development, below the Coral Rag with *Cidaris florigemma*, of highly fossiliferous limestones with *Trigonia Meriani*, *Lima rigida*, and *Ammonites plicatilis*. These shell-beds thin out or disappear near Oxford. At Heddington another shell-bed, with abundance of *Cidaris florigemma*, occurs in the Coral Rag.

The Cambridge Reef.—This remarkable outlier is composed entirely of the Coral Rag, containing a rich and special fauna, the characteristic *Cidaris florigemma* determining its true character. The authors believe the Elsworth rock to be an exceptional development of the Lower Calcareous Grit. The Rev. T. G. Bonney, in his 'Cambridgeshire Geology,' has carefully described this "reef," and gives a list of the characteristic fossils obtained. No less than 58 species are known—Cœlenterata 7, Echinodermata 7, Annulosa 4, Brachiopoda 1, Pelecypoda 23, Gasteropoda 11, Cephalopoda 5 species.

The Yorkshire Basin.—The Lower Calcareous Grit is the most constantly developed of all the Corallian deposits. In the Howardian hills at Grimston and Walton it is about 60 feet in thickness; in the western and northern hills (Hambleton and Newtondale) it increases to 100 feet. The fauna of the Lower Limestone has much

in common with that of the Lower Calcareous Grit. This is especially the case in the eastern districts; the maximum thickness of the Lower Limestones near Kirkby Moorside is about 150 feet.

The Middle Calcareous Grit is irregular and uncertain; it occurs at Filey Brig. No certain indication of the Middle Grit is to be seen in the Howardian hills.

The Upper Limestones (not seen on the coast) are throughout divisible into Coralline Oolite and the overlying Coral Rag. They contain peculiar fossils; east of the Derwent they are thick and rich in Echinoidea and Mollusca.

The Supracoralline beds are fully developed and regular; in the arenaceous type, as Upper Calcareous Grit, they "attain their maximum thickness in the extreme western bay of the Vale of Pickering." The Upper Calcareous Grit of Yorkshire possesses peculiar features, and contains a series of fossils partially Kimmeridgian.

Messrs. Blake and Hudleston show how inappropriate is the term "Coral Rag" as a designation for the whole of the limestones, grits, and clays above the Oxford Clay, or between that formation and the Kimmeridge Clay. The lower beds of the "Corallian group" are markedly Oxfordian in the character of their fauna; and before the members of this fauna died out "Kimmeridgian forms became their companions, and ultimately supplanted them." Their researches have clearly shown us that it is to Yorkshire that we must look for our type with which to compare the rocks and fossils of the same group through England, "and thence take our general terms."

The authors conclude their elaborately worked-out paper by stating succinctly the leading characteristics of each of the six groups, and drawing conclusions from their researches (*vide* Quart. Journ. Geol. Soc. vol. xxxiii. pp. 389–90).

Forty-nine continental species are added to the Molluscan fauna of the British Upper Jurassic Rocks, and 25 new species which have occurred to the authors in these rocks during their researches, thus adding to the British Upper Jurassic fauna 74 new forms. Of the foreign species 21 are Gasteropoda and 28 Lamellibranchiata.

Mr. Hudleston, in the third part of his memoir on the Yorkshire Oolites, published in the Proceedings of the Geologists' Association in October 1878, enumerates no less than 288 species of all groups as occurring in the four divisions of the Corallian Rocks of Yorkshire, viz.

I. The Lower Calc Grit (in part) and Lower Limestone,
II. Coralline Oolite group,
III. Coral Rag,
IV. Supracoralline.

The Lower Calcareous Grit has yielded 100 species, the Coralline Oolite 124 species, the Coral Rag 138 species, and the Supracoralline 22 species: 40 species are Oxfordian, coming up from that horizon

and ranging into one or other of the Corallian divisions; but only 6 species pass to the Kimmeridgian stage above; the fauna therefore of the true Corallian Rocks of Yorkshire numbers 243 species.

The grouping falls under eighteen classes, in which occur the 288 species (omitting the Plantæ, 285).

The following Table (XV.) is the numerical result of Mr. Hudleston's researches upon the Lower Calcareous grit, Coralline Oolite, Coral Rag, and Supracoralline beds:—

Table XV.—*Showing the Fossils (numerically expressed) of the Lower Calcareous Grit, the Coralline Oolite, Coral Rag, and Supracoralline beds.*

Classes.	Known species.	Lower Calcareous Grit.	Coralline Oolite.	Coral Rag.	Supracoralline beds.
Protozoa	4	3	1	1	
Cœlenterata	10	4	2	9	
Annelida	5	3	...	2	1
Crustacea	2	2	1		
Asteriadæ	1	1			
Crinoidea	3	2	...	3	
Echinoidea	19	8	8	13	
Bryozoa	1	1			
Brachiopoda	8	5	...	3	
Monomyaria	51	19	31	28	
Dimyaria	89	27	47	28	12
Gasteropoda	57	9	16	45	2
Ammonites	16	7	3	3	5
Belemnites	7	2	3	...	2
Nautili	2	1	1	1	
Pisces	6	1	4	1	
Reptilia	4	3	4	1	
Plantæ	3	2	3		
	288	100	124	138	22

Reference is often made to Phillips's 'Geology of Yorkshire;' and when the fauna of Yorkshire was under consideration, I found it convenient to construct the following Table (XVI.) showing the distribution of the species through all the Jurassic formations. I insert it here, after the paper by Mr. Hudleston, as the most fitting place. Six of the seven divisions of the Mollusca play a very important part in the palæontology of the county, and show singular and unexpected results. I have added a column for the number of appearances for each class through the formations. Professor Phillips did not add much to the fauna of Yorkshire in his last edition; he chiefly corrected the nomenclature and recast the literature, the chief palæontological addition occurring among the Plantæ.

TABLE XVI.—*Giving the numerical Analysis of the Species named in Prof. Phillips's 'Geology of Yorkshire,' to show their Stratigraphical Distribution.*

Classes.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coralline Oolite and Calc. Grit.	Kimmeridge Clay.	Portland Oolite.	Appearances.
Plantæ	...	...	...	25 86	...	...	...	...	...	...	25 86
Protozoa	...	...	...	...	...	...	...	3 3	...	...	3 3
Cœlenterata	...	...	...	3 4	...	...	...	6 8	...	...	9 12
Echinoidea	...	...	...	5 5	4 4	...	...	11 15	...	...	20 24
Asteroidea	...	7 8	...	2 3	...	1 2	...	1 1	...	...	11 14
Crinoidea	1 1	...	2 3	...	...	...	...	1 1	...	...	4 5
Annelida	...	...	...	2 8	2 5	...	...	...	...	...	4 13
Crustacea	...	...	...	1 1	2 2	1 2	1 2	1 2	...	...	6 9
Bryozoa	...	...	...	1 1	1 1	...	...	1 1	...	...	3 3
Brachiopoda	1 1	2 5	1 2	2 9	3 9	1 1	1 1	3 5	3 3	...	17 36
Monomyaria	5 9	2 7	1 1	10 24	11 27	6 11	3 3	7 24	3 3	...	48 109
Dimyaria	9 12	10 11	7 12	30 58	21 52	14 23	...	22 46	3 5	2 2	118 221
Gasteropoda	...	5 5	...	13 29	...	6 11	...	13 22	...	...	37 67
Belemnites	1 7	1 7	1 18	1 3	...	1 3	...	1 2	...	...	6 40
Ammonites	1 109	1 13	1 41	1 5	1 3	1 33	1 3	1 8	1 9	1 6	10 230
Nautili	1 1	...	1 3	1 1	...	1 1	...	...	...	...	4 6
Pisces	...	...	10 15	...	...	...	1 1	2 2	...	...	13 18
Reptilia	...	...	3 10	3 3	...	1 1	...	2 2	1 1	...	10 17
	19 140	28 56	27 105	100 240	45 103	33 88	7 10	75 142	11 21	3 8	348 913

Succeeding the paper on the Corallian Rocks of England, by the Rev. J. F. Blake, M.A., and W. H. Hudleston, M.A., and more or less a companion to or continuation of the same important subject, I have now to notice the exhaustive paper "On the Portland Rocks of England," by the Rev. J. F. Blake, who alone undertook this important investigation. Like the previous paper by himself and Mr. Hudleston, this interpretation of the distribution of the Portland Rocks has had no equal since the memorable and masterly memoir by Dr. Fitton "On the Strata between the Chalk and Kimmeridge Clay in the South-east of England" (Transactions of the Geological Soc. ser. 2, vol. iv. pp. 103–388). I shall have to notice a subsequent paper by Mr. Blake "On the Correlation of the Upper Jurassic Rocks with those of the Continent—Part I. the Paris basin," which unites the labours of Hudleston and himself with those of the French geologists in a more correct reading of the Anglo-French Jurassic rocks, especially those of the Anglo-Parisian basin, to which his first paper is devoted. Mr. Blake and Mr. Hudleston, in the introduction to their paper upon "the Corallian Rocks of England," regarded the Portlandian as a local development in a great "Pelolithic" formation, determining not to extend the term "Corallian" to beds of probably various ages which agreed "only with our own in occurring in the Oxford-Kimmeridge seas, and in containing corals." Doubtless in England we had two "episodes," the "Corallian and Portlandian." How far the continental "episodes" may be correlated with ours, has yet to be determined. It is the endeavour of Mr. Blake, in his paper, to show that the rocks which have been called Middle and Lower Portlandian at Boulogne have their representatives in the Kimmeridge Clay. He describes the relations of the various parts of the Portlandian episode with each other, thus endeavouring to obtain some "insight into those final oscillations which converted the open argillaceous ocean into the lake-bearing and cycad-growing continent of the Purbecks."

Mr. Blake divides the subject of his paper into six geographical areas:—

1. The Island of Portland.
2. St. Alban's Head and Kimmeridge.
3. Upway.
4. The Vale of Wardour.
5. Devizes.
6. Swindon.

The Portland Oolite of Portland he divides into 9 beds, the sandy series below into 5, making all together 14 divisions. Each of the 9 limestone beds possesses distinctive species; and such being the case, I name these and the forms illustrating them :—

	Bed	Fossils
Portland Stone and Sands.	Bed No. 1. The Roach, shelly limestone with......	*Cerithium portlandicum* (confined); *Sowerbya Dukei*, *Buccinum naticoides*, *Trigonia gibbosa*, *Lucina portlandica* (rare), *Pecten lamellosus; Ostrea expansa*, and *Natica elegans* (abundant).
	„ 2. The Whit bed.........	*Ammonites giganteus*, confined.
	„ 3. The Curf...............	*Ostrea solitaria*, *Isastræa oblonga*.
	„ 4. The Base bed	*Isastræa oblonga*, with its perforating *Lithodomi*.
	„ 5. Upper part, *Trigonia*-bed	*Trigonia gibbosa*.
	„ 6. Upper part solid flint, lower part rubble.	
	„ 7. *Serpula*-bed	*Serpula gordialis*, *Ostrea multiformis*.
	„ 8. Main mass of flinty series..................	*Ammonites boloniensis*, *Trigonia gibbosa*, *T. incurva*, *Perna*.
	„ 9. The shell-bed	*Ammonites pseudogigas*, *Am. triplex*, *Pleurotomaria rugata*, *P. Rozeti*, *Cardium dissimile*, *Cyprina elongata*, *Lima rustica*, *Pecten lamellosus*, *Trigonia gibbosa*, *T. incurva*, *Pleuromya tellina*.
	„ 10. Blue marl	No fossils.
	„ 11. Marl and sand, nodular (cement-stone)	*Mytilus autissiodorensis*, *Pecten solidus*, *Cyprina implicata*, *C. elongata*, *Ammonites biplex*.
	„ 12. *Exogyra*-bed	*Exogyra bruntrutana* (the only fossil occurring).
	„ 13. Yellow sandy bed ...	*Cyprina implicata*, *Arca*.
	„ 14. Sandy marl, gradually changing into Kimmeridge Clay.	*Ammonites biplex*, *Natica incisa*, *Lima boloniensis*, *Pecten Morini*, *Avicula octavia*, *Trigonia incurva*, *T. muricata*, *T. Pellati*, *Rhynchonella portlandica*, *Discina Humphriesiana*, *Pleuromya tellina*.

Kimmeridge Clay below.

Full details of the physical character of these 14 divisions at the Isle of Portland are given by Mr. Blake; and regarding this on the whole as the type section, the other five areas named may be compared with it.

St. Alban's Head and Kimmeridge.

The first 10 beds in the St. Alban's Head section can be more or less correlated with those of the Isle of Portland; the beds numbered 15 and 16 are in excess of the Portland-sand series at Portland, and add about 130 feet to the section. The fossils are much the same as in the several Portland-Isle beds, and need no comment here.

Mr. Blake discusses the question of difference between the Boulogne and Kimmeridge sections, and the introduction of the terms Middle and Lower Portlandian by the French geologists. Comparative sections at Boulogne and Kimmeridge are given on page 197; and the difference between the two sections is shown. The *English* Kimmeridge beds (shales and clays) show that there are 1100 feet between the base of the Portland Stone and the lowest part of the Kimmeridge Clay *visible* (base not seen); but the total

thickness of the Kimmeridge at Boulogne between the Portlandian and Corallian is only 450 feet. In England, as Mr. Blake states, "we possess the *normal* formation to which the name Kimmeridge was originally applied; while at Boulogne we find an 'episode' having no relation to the Portlandian above, but to which the name of 'Boulognian' may be given." "The *upper part* of their 'Middle Portlandian' is our Portland Sand," and contains the characteristic shells *Mytilus autissiodorensis*, *Astarte scalaria*, *A. Sæmanni*, *Pecten Morini*, *Avicula octavia*, *Lima boloniensis*, *Perna Bouchardi*, and *Pecten lamellosus*. "The lower part of their 'Middle Portlandian' consists of soft sandy marls and shales, with cement-stone bands, not at all unlike the top of the Kimmeridge at Chapman's Pool. The *Cardium Morinicum*, *Belemnites Souichii*, and *Discina latissima* serve to prove the identity."—(Blake, Quart. Journ. Geol. Soc. vol. xxxvi. p. 196).

Vale of Wardour.

The Portland series here commences with the beds containing *Cerithium portlandicum*; and the fauna of the 10 succeeding beds I will notice as before.

Portland Stone and Sands.	Bed No. 1.	Fine-grained brown oolite with......................	*Cerithium portlandicum.*
	" 2.	Finely oolitic	*Cerithium portlandicum.*
	" 3.	White chalk (like Upway), flints	*Pecten lamellosus*, *Cardium dissimile*, *Lucina portlandica*, *Pleuromya tellina*, *Ostrea expansa*, *Trigonia gibbosa.*
	" 4.	Fossiliferous bed	*Astarte rugosa*, *Cerithium concavum*, *C. Bouchardianum*, *Nerita transversa*, *Neritoma sinuosa.*
	" 5.	*Trigonia*-bed	*Trigonia gibbosa.*
	" 6.	Fine freestone...............	*Ammonites boloniensis*, *A. biplex*, *Isastræa oblonga.*
	" 7.	Doubtful in thickness &c.	
	" 8.	Yellow impure sand	No fossils.
	" 9.	Impure calcareous bed, with Lydian stone or glauconite	*Trigonia Pellati*, *T. variegata*, *T. concentrica*, *T. Micheloti*, *Mytilus jurensis*, *Perna Bouchardi*, *Pecten concentricus*, *Exogyra bruntrutana*, and *Serpula.*
	" 10.	Hard impure calcareous bed	*Trigonia Pellati*, *Ostrea bruntrutana.*
	" 11.	Yellowish-grey calcareous stone	No fossils.

Swindon.

These richly fossiliferous and abnormal beds are the most extensive out of the Portland and Purbeck areas; and the unconformability of the Purbeck strata upon the Portlandian beds admits of no doubt. Mr. Blake's notice of these great quarries is the only detailed one yet given; and, as he truly remarks, "a more complicated and, at the same time, instructive series of sections," is hardly to

be seen. It has also been my good fortune to spend an entire day in these quarries; and I fully indorse his reading of the succession. (*Vide* Mr. Blake's minute description, Quart. Journ. Geol. Soc. vol. xxxvi. pp. 203–213.)

The general succession and contents I give, as in previous cases.

Bed No. 1. Portland Rock.	
„ 2. Calcareous sands (basal sands) = the Tisbury stone	*Trigonia gibbosa, Ostrea solitaria, Lima rustica, Mytilus unguiculatus, Cyprina pulchella, Corbula dammariensis,* and *Pleuromya tellina.*
„ 3. Rubbly and glauconite beds (*Trigonia*-beds).	*Trigonia gibbosa*; 20 *species occur* in this and the same beds at Coate.

These beds, Mr. Blake believes, succeed those of the Great Swindon Quarry in a downward direction. The *Trigonia*-beds in the Coate section have yielded to Mr. Blake 22 species, 17 of which are bivalves.

The Bourton outlier is a marked feature in the history of the Swindon Portland rocks. Palæontologically the Bourton beds are peculiar. *Echinobrissus Brodiei,* so rare elsewhere in the Portlandian series, is here abundant; the true *Cardium dissimile* is replaced by *C. Morinicum,* a shell characteristic of the lowest true Portland beds of Boulogne; downwards, a thick bed of limestone contains *Perna Bouchardi,* and its base is full of various dark-coloured stones or pebbles. "Among them are Lydian stones, light-coloured quartz, also hardened phosphate nodules derived from previous formations" (Kimmeridge Clay). The inference drawn by Mr. Blake relative to these facts is one of considerable physical importance. These pebble-beds do not occur in the Portland area; hence Mr. Blake assumes that "these more northern districts were more rapidly upheaved than those to the south, and brought earlier into the conditions necessary for calcareous deposits" (*loc. cit.* p. 210).

Again, the author gives reasons for believing that the Purbecks of Swindon differ from those of the southern districts through difference of character. In the Swindon Purbecks we have uniform deposits over considerable distances, lying on unevenly but not deeply eroded Portland rocks. In the southern Purbecks there are carvings of rivers, transported blocks, and the rapid dying-out of deposits—all features characteristic of subaerial action. Seeing, then, that we have reason to believe that the earliest Swindon Portland Stone *antedated* that at Portland, we are justified in concluding that the land here emerged sooner and more rapidly from the ocean; hence the regular deposits reached only the "basal sands." Finally, Mr. Blake believes that the "newly-risen Portland was *carved out by the river* whose course is still marked in the quarry, and that the more gradual elevation of the south left time for the deposition of the "Whit bed" and "the Roach," and that when the sea was finally expelled its place was taken by a large shallow lake, ofttimes dried up, and during minor oscillations supporting forests of *Cycads* and *Conifers,* the growth of which on the spot, well known there, is

sought for in vain at Swindon. We are led, therefore, *to the apparently strange conclusion that the freshwater strata of Swindon, though unconformable to those below, and representing the Purbeck in the order of events, are probably in point of actual time as old as some parts of the Portland*" (loc. cit. p. 211). From the 4th and 5th beds, or sandy beds, Mr. Blake enumerates a large fauna, including no less than 26 genera and 41 species, 35 of which are bivalves, 4 univalves, and 2 Ammonites (*A. biplex* and *A. pectinatus*). This fauna is very distinct from that of the Portland rock. *Trigonia gibbosa* and *Cardium dissimile* are unknown; many of the species are characteristic of the so-called Middle Portland of Boulogne, or of the highest Portlandian beds of other districts.

Buckinghamshire.

The extension of the Portland series through Oxfordshire and Buckinghamshire is characterized by much the same conditions as that of Swindon, especially through the Limestones, which may be an expansion of the *Trigonia*-beds; and it is probable that no higher beds were ever deposited in this area above those now exposed. Seven beds are recognized in Buckinghamshire. "The creamy Limestones of the Brill and Crendon" have yielded a remarkable assemblage of fossils, no less than 29 genera and 45 species; and the Rubbly Limestone of bed No. 4, 19 genera and 35 species. The absence of oolitic rocks is remarkable; the Brill Purbeck beds seem to be the only ones possessing that character.

The Rubbly beds at Lodge Hill have yielded a singular assemblage of fossils—few Gasteropoda, but many genera of Bivalves. Mr. Blake mentions the important introduction of *Ammonites pectinatus* of Phillips as argument for correlation. Numerically the grouping is as follows:—

Ammonites . .	1 genus and	5	species.	
Gasteropoda .	2 genera and	2	,,	
Dimyaria . . .	9 ,,	18	,,	7 of these are *Trigoniæ*.
Monomyaria .	5 ,,	8	,,	
Annelida . . .	1 ,,	1	,,	
Crustacea . . .	1 ,,	1	,,	
	19	35		

The Portland rocks of Buckinghamshire probably do not exceed 60 or 70 feet in thickness, including the sands. This is a considerable reduction from those of Oxfordshire and Wiltshire. Mr. Blake accounts for this in part through the reduction in thickness of the Portland Sands; and he suggests, with regard to the stone, that in Buckinghamshire we may have "thin representatives of all the Portland deposits, elsewhere reaching a far greater thickness," or "that we may match these beds with some part of those at Swindon, and that we have in them only a portion of the series elsewhere found."

Mr. Blake gives a list of fossils common to the Limestones of

Buckinghamshire and the Trigonia-beds of Swindon and Bourton, and peculiar to these or most common in them. They are:—

Ammonites pectinatus.	*Pleuromya tellina.*
Natica elegans.	*Thracia tenera.*
Trigonia Voltzii.	*Mytilus unguiculatus.*
Cyprina elongata.	—— *boloniensis.*
Cypricardia costifera.	*Echinobrissus Brodiei.*
Anisocardia pulchella.	

The *Natica*, *Cyprina*, *Cypricardia*, *Anisocardia*, *Pleuromya*, and *Echinobrissus* occur in the creamy limestones, which thus range no higher than the beds at Swindon. Mr. Blake therefore regards "the whole of the limestones of Buckinghamshire as an expansion of the *Trigonia*-beds of Swindon, except that the brashy beds at the top correspond to *part* of the '*basal sands*' of the latter place, but not to the whole."

The author then summarizes the contents of his paper, and recapitulates the facts arrived at, which may be stated as follows:—

1. In all the sections near the coast the Purbeck beds are separated from the Portland by a line of clay.
2. The *uppermost* bed of the Purbeck is not always the same, and the line of junction, though not eroded, is "irregular."
3. The Portland series (reading downwards) shows first the "Whit bed" and "Roach" characterized by particular fossils, and especially by *Ammonites giganteus*, and locally unconformable to the bed below.
4. The flinty series is divisible into several parts, very fossiliferous at the base, and characterized by *Ammonites boloniensis.* This is thickest at St. Alban's Head, and becomes chalky at Upway.
5. The Portland Sands contain a variety of beds (clays, cement-stones, and oyster-beds), and have a fauna distinct from that of the limestones above; but these characters are not constant.
6. "In the Vale of Wardour the Purbeck is separated from the Portland by a band of clay, and the succession is very similar. Below the Limestones the true Portland Sand is very thin and brown."
7. At Swindon the relations of the Purbeck to the Portland are remarkable; the Portland is carved out in hollows which contain rolled blocks of it, evidencing a land surface and rapid changes. This erosion may have taken place in Portland times, as the uppermost part of the Portland beds here corresponds only to the top of the Tisbury Freestone.
8. The Portland sands are found at Swindon below the Trigonia-beds, and occur in the form of extremely fossiliferous glauconitic sandstones or shell masses. They contain a well-marked and almost restricted fauna.
9. The districts of Oxfordshire and Buckinghamshire are formed on the same model. The Purbeck beds of Bucks lie uniformly on the Portland rocks as in the south; but the

underlying Portland Limestone corresponds to the *Trigonia*-bed of Swindon. Hence the Purbeck beds of Oxfordshire and Buckinghamshire are of earlier date than the Portland of Swindon, and still earlier than those of the Isle of Purbeck, and were formed in Portland times.

10. The fossiliferous Portland Sand becomes much diminished in importance, but continues its glauconitic character, to the north, while the lowest sands with their rounded masses are continued to Shotover and Thame and then nearly disappear.
11. Thus the Portland Sand had two maxima—one to the north of Tisbury, and one to the south; but as regards the Portland Stone the oldest beds are found in the north, and as we go south later and later deposits are successively introduced before the traces of freshwater conditions appear.
12. These were the final result of the gradual elevation in all cases, and were not of the same age throughout, but followed immediately on the period of the beds below (*loc. cit.* pp. 221, 222).

Little trace of a Portlandian episode can be detected at Speeton in Yorkshire, or beneath Sussex, and Mr. Blake believes "that the elevation which introduced the circumstances capable of yielding sandy and calcareous deposits took place sporadically. So far as our knowledge at present extends, the earliest rise took place along the main axis between Boulogne and the Mendips. . . . . Further physical changes of a nature unknown to us brought about the denudation of some sandy rocks and developed the great sandbanks which pass from Swindon to Shotover and die away to the north-east, and which diminish from St. Alban's Head towards Portland and Upway, and are not to be recognized in the Boulogne area."

The question of the removal of the Portland Sands to the Kimmeridge Clay is commented upon; and the propriety of the French geologists uniting the upper part of the Kimmeridge Clay with the Portland sands, and calling them the "Middle Portlandian," is clearly stated. Mr. Blake has added a complete table of Portlandian fossils, adding 17 new species, and introducing 8 continental forms (French) as new to Britain, thus increasing our Portlandian fauna by 25 additional species. I have reconstructed the table so as to read uniformly with those prepared in other portions of my address for this year and the year 1880–81; for the names of the species *vide* Mr. Blake's Table, *loc. cit.* pp. 225–227.

TABLE XVII.—*The Numerical Distribution of the Portlandian Species.*

	Genera.	Species.	Base at Tisbury.	Shotover and Glauconite Sands.	Swindon Sands and Clays.	Lower Sands of the coast.	Upper Sands of the coast.	Rubble beds of Bucks and Oxon.	Creamy Limestone of Bucks and Oxon.	Trigonia-beds of Swindon.	Freestone at Tisbury and Swindon.	Upper beds of Swindon & Tisbury.	Chalky series at Cheeksgrove.	Flinty series of the coast.	Building-stone of Portland.	Appearances.
Belemnites	1	2	...	...	...	$^{1}_{1}$	...	...	$^{1}_{1}$	...	...	...	...	...	...	$^{2}_{2}$
Ammonites	1	8	...	$^{1}_{3}$	$^{1}_{2}$	$^{1}_{1}$	$^{1}_{4}$	$^{1}_{5}$	$^{1}_{3}$	$^{1}_{4}$	$^{1}_{3}$	...	...	$^{1}_{5}$	$^{1}_{1}$	$^{10}_{31}$
Gasteropoda	14	30	...	$^{1}_{1}$	$^{5}_{5}$	$^{1}_{1}$	...	$^{3}_{3}$	$^{8}_{12}$	$^{2}_{3}$	...	$^{6}_{8}$	...	$^{4}_{6}$	$^{5}_{6}$	$^{35}_{45}$
Dimyaria	26	64	$^{4}_{8}$	$^{3}_{5}$	$^{14}_{23}$	$^{7}_{10}$	$^{7}_{11}$	$^{10}_{21}$	$^{17}_{24}$	$^{11}_{19}$	$^{5}_{6}$	$^{7}_{7}$	$^{4}_{5}$	$^{11}_{11}$	$^{4}_{4}$	$^{104}_{154}$
Monomyaria	10	24	$^{3}_{3}$	$^{3}_{4}$	$^{7}_{11}$	$^{4}_{4}$	$^{4}_{6}$	$^{5}_{8}$	$^{7}_{11}$	$^{3}_{4}$	$^{3}_{3}$	$^{2}_{2}$	$^{2}_{2}$	$^{6}_{9}$	$^{2}_{2}$	$^{51}_{69}$
Brachiopoda	4	4	...	...	$^{3}_{3}$	...	...	...	...	...	...	...	...	...	$^{1}_{1}$	$^{4}_{4}$
Annelida	1	2	...	$^{1}_{1}$	...	...	...	$^{1}_{1}$	$^{1}_{2}$	...	...	...	...	$^{1}_{1}$	...	$^{4}_{5}$
Crustacea	1	1	...	...	...	...	$^{1}_{1}$	...	...	...	...	...	...	...	...	$^{1}_{1}$
Echinoidea	2	3	...	$^{1}_{1}$	$^{1}_{1}$	...	...	...	$^{2}_{2}$	...	...	...	...	...	...	$^{4}_{4}$
Cœlenterata	1	1	...	...	...	...	...	...	...	...	$^{1}_{1}$	...	...	$^{1}_{1}$	...	$^{2}_{2}$
Pisces	2	3	...	...	...	...	...	$^{1}_{1}$	...	...	...	...	...	$^{1}_{3}$	...	$^{2}_{4}$
Reptilia...............	4	4	...	$^{1}_{1}$	...	...	...	$^{1}_{1}$	...	...	...	$^{1}_{1}$	...	$^{1}_{1}$	...	$^{4}_{4}$
	67	146	$^{7}_{11}$	$^{11}_{16}$	$^{31}_{45}$	$^{14}_{17}$	$^{13}_{22}$	$^{22}_{40}$	$^{37}_{55}$	$^{17}_{30}$	$^{10}_{13}$	$^{16}_{18}$	$^{6}_{7}$	$^{26}_{37}$	$^{13}_{14}$	$^{223}_{325}$

The plate of comparative sections given by Mr. Blake, on the scale of 48 feet to an inch, admirably shows the proportional thickness and development of the different horizons through the country, and also explains the table of fossils prepared by Mr. Blake, and my numerical analysis reconstructed to show the generic and specific values in one table. The generalized theoretical section on the same sheet will bear close attention and scrutiny. The intermittent thickening and thinning of the series from Portland and St. Alban's Head on the coast to Buckinghamshire, diagrammatically explains the vertical columns above.

The next communication naturally follows on the two previous papers by Mr. Blake, viz. the Portland Rocks and the Kimmeridge Clay, and the third by Messrs. Blake and Hudleston, on the Corallian rocks. These papers referred to the development of these formations in Britain only. The one I have now to notice is "On the Correlation of the Upper Jurassic rocks of England with those of the Continent.—Part. I. The Paris Basin, by the Rev. J. F. Blake, M.A." The author shows that while the normal deposits of the period commencing with the Oxford Clay and continuing to the close of the Jurassic era were essentially argillaceous, the uniformity was broken by the deposition of the calcareous Corallian rocks—but that, in spite of episodes, there is a continuity both in the physical and biological features, uniting the whole into one great group to which the term Upper Jurassic is appropriately given (p. 497). The rocks hitherto called Corallian in England comprise much that is classed with the Oxfordian by the French geologists.

The Upper Jurassic rocks of France occur in two distinct areas. The Seine and the Loire and smaller rivers drain the more northern; the more southern is a continuation of the Swiss Jura, and lies to the south of the central plateau of Auvergne.

The former (Seine and Loire) constitutes the basin of Paris, and is the subject of Mr. Blake's paper. Within the Paris-basin area there are five ranges, of unequal size and importance, separated from each other by intervals in which either older or newer rocks occupy the surface of the ground. These are:—

1. From the Ardennes to the Cher.
2. The two Charentes.
3. Normandy with Orne and Sarthe.
4. The Pays de Bray.
5. The Boulonnais.

The physical features and palæontology of these five areas are correlated by Mr. Blake with the Upper Jurassic rocks of Britain.

I. From the Ardennes to the Cher.

The classification of the rocks of this area has been completed by MM. Sauvage and Buvignier*. The 3 divisions are:—I. The

* Sauvage and Buvignier, 'Statistique Minéralogique et Géologique du dépt. des Ardennes.'

Upper Group, containing (A) marls with *Exogyra virgula*, (B) the *Astarte* Limestone; II. The Coral Rag; and III. The Oxfordian group, in 3 subdivisions.

The Oxfordian Group.—The nodular beds contain a characteristic fauna precisely that of our own, viz. *Am. cordatus*, *Modiola bipartita*, *Perna quadrata*, *Pecten fibrosus*, *Ostrea dilatata*, and *Rhynchonella Thurmanni*. These represent the "Nothe Grits" of Weymouth and the Lower Calcareous Grits of Yorkshire. Succeeding these are beds which in Yorkshire belong to the Passage-series above the Lower Calcareous Grits. The noticeable shell *Trigonia saintonensis*, Lycett (*T. spinifera*, D'Orb.), occurs in both places, and, with *Ammonites oculatus*, serves to show the Oxfordian character of the beds.

The "Ferruginous Oolite" Hébert refers to the Middle Oxfordian, which contains a well-marked fauna of that horizon. Above there exist certain marls with *Cidaris florigemma* and *Pecten articulatus*.

The Meuse Department.—Buvignier gives, for this department, the following classification in ascending order:—

Upper Jurassic.

I. Barrois Limestone in 3 subdivisions, 600 feet thick.
II. Virgulian Clays, 150 feet.
III. Astartian Limestones in 2 subdivisions, 400 feet.

Middle Jurassic.

I. Coral Rag in 2 subdivisions, 400 feet.
II. Oxford Clay in 3 subdivisions, 500 feet.

I must refer the student to the admirably detailed analysis of the geology and palæontology of this department by Mr. Blake (*vide* pp. 505–516). There is but little in this series to be correlated with that of Britain.

The Haute-Marne Department.—The Upper Jurassic rocks of this department may be considered as typical in the Paris basin. Royer* divides the series under the 8 following heads:—

A. Portland, under 3 petrological subdivisions.
B. Kimmeridgian.
C. Astartian, under 2 petrological subdivisions.
D. Coralline Oolite.
E. Compact Corallian Limestone, under 2 subdivisions.
F. Upper Oxfordian marls.
G. Middle ,, ,,
H. Lower ,, ,,

The newer classification is far more complicated and, as published by MM. de Loriol, Royer, and Tombeck, is as follows:—

* Royer, "Note sur les Terrains Jurassiques supérieurs et moyens de la Haute Marne," Bull. Soc. Géol. France, sér. 2, vol. ii. p. 705.

Portlandian.

1. Zone of *Cyrena rugosa*, with 3 subdivisions.
2. Zone of *Cyprina Brongniarti*, with 3 subdivisions.
3. Zone of *Ammonites gigas*, with 4 divisions.
   a. Bure Oolite.
   b. Limestone with *Am. irrius*.
   c. Marls with *Hemicidaris purbeckensis*.
   d. Lithographic Limestone with *Amm. rotundus*.

Kimmeridgian.

1. Zone of *Amm. caletanus* = Virgulian, with 2 subdivisions.
   a. Alternations with *Am. erinus*.
   b. Marls with *Am. eumelus*.
2. Zone of *Amm. orthocera* = Pterocerian, with 6 subdivisions.
   a. Perforated Limestone.
   b. Marly Limestone with *Dysaster granulosus*.
   c. Limestone with *Isocardia striata*.
   d. Marls with *Rhabdocidaris Orbignyana*.
   e. Marls with *Ceromya excentrica*.
   f. Perforated Limestone with *Pterocera*.

Corallian or Sequanian.

1. Second zone of *Terebratula humeralis*, Astartian Limestone.
2. " " *Cardium corallinum*, La-Mothe Oolite.
3. First " *Terebratula humeralis*, with 6 subdivisions.
   a. Lithographic Limestone.
   b. Saucourt Oolite.
   c. Limestones with *Nautilus giganteus*.
   d. Upper Rubbly Limestone with *Cidaris florigemma*.
   e. Limestone with *Am. achilles*.
   f. Limestone with *Am. bimammatus*.
4. First zone of *Cardium corallinum* and zone of *Hemicidaris crenularis*.
   a. Upper Marls without fossils.
   b. Diceras-Oolites and lower rubbly Limestones with *Cid. florigemma*.
   c. Lower Marls without fossils.

Oxfordian.

Zone of *Amm. transversarius*.
   a. Beds with *Amm. Henrici* and *Am. oculatus*.
   b. " " " *Babeanus*.
   c. " " " *Martelli*.

I feel bound to give this complicated classification on account of the minute manner in which the typical or characteristic fossils are assigned to their respective horizons, for comparison with our English Upper and Middle Jurassic rocks, and also to show the method of work adopted by some continental authors.

Department of the Aube.—Leymerie, as far back as 1846, admirably described the geology of this department*. He classified the rocks as follows:—

Upper Jurassic.

1. Portland Limestone, 330 feet.
2. Marls and Limestones with *Exogyra virgula*, 250 feet.

* Leymerie, 'Statistique du Département de l'Aube,' 1846.

MIDDLE JURASSIC.

1. Astartian Limestone, 320 feet.
2. Nodular white Limestones = Coral Rag, 40 feet.
3. Lower Coral Limestone.
   a. Compact Limestone, 80–100 feet.
   b. "Levique" Limestone, 50 feet.
   c. Oolitic Shell-Limestone, 80–100 feet.

DEPARTMENT OF THE YONNE.—Leymerie, Raulin, and Cotteau have described the rocks of this department, the first two authors in 1858, and Cotteau in 1865 and 1868, in the latter year associated with De Loriol.

Leymerie and Raulin classify the rocks as follows:—

UPPER JURASSIC.

1. Portland Limestones, 135 feet.
2. Kimmeridgian Marls and Limestones, 330 feet.

MIDDLE JURASSIC.

1. Astartian Limestone.
2. White Coral Limestone.
3. Upper Oxfordian Limestone.
4. Middle Oxfordian Limestones or Marls.
5. Lower Oxfordian Ironstone.

Cotteau's subdivisions differ chiefly in the Sequanian and Corallian series.

PORTLANDIAN.

1. Zone of *Pinna suprajurensis*.
2. ,, *Ammonites gigas*.

KIMMERIDGIAN OR SEQUANIAN.

1. White Limestones.
2. Lithographic Limestones.

CORALLIAN.

Diceras-beds.

OXFORDIAN.

Zone of *Amm. plicatilis* and *Cidaris florigemma*.

Along the banks of the Yonne certain beds are exposed that can be without doubt referred to our true Coral Rag, only that we do not possess the Diceras-beds (*vide* Blake, *loc. cit.* pp. 530–537).

DEPARTMENT OF NIÈVRE.—Ebray in 1864, and Douvillé and Jourdy in 1875, have described the geology of this department. The classification, chiefly compiled from the country along the banks of the Loire, is as follows:—

KIMMERIDGIAN.

Astartian Limestone.

CORALLIAN.

1. Upper Lithographic Limestone.
2. Oolite with small *Diceras*.
3. Chalky Limestone.
4. Lithographic Limestone.
5. Oolite of La Charité with *Diceras arietinum*.
6. Marly Limestone and Lower Lithographic Limestones.

ARGOVIAN.

1. Sponge-marls with *Ammonites canaliculatus*.

Department of the Cher.—As far back as 1838 this department was described by Fabre; followed by Boulanger and Bertera in 1850 (Texte explicatif de la carte géologique du Cher); but Douvillé and Jourdy in 1875 (Bull. Soc. Géol. France, sér. 3, vol. iii. p. 93) have most recently described the area. Their classification is as follows:—

Kimmeridgian.

1. Limestone of Barrois.
2. Virgulian Marls.
3. Astartian Limestone.
    - A. Marls and Nodular Limestones.
    - B. Nerinæan Oolite.
    - C. Fucoidal Marls and Limestones.

Corallian.

4. Upper Lithographic Limestones with *Amm. achilles*.
    - D. Limestone with *Pinna*.
    - E. Compact Limestone.
5. Chalky Limestone of Bourges.
6. Lithographic Limestones.
7. Sponge-limestones with *Am. marantianus*, *Am. bimammatus*, and *Am. plicatilis*.

II. The two Charentes.

The main question to be solved in this district of the Charentes was the age of the so-called "Portland" and even "Purbeck" beds, to ascertain whether there are any rocks corresponding to those that we know as such in England. Coquand in 1858 ('Statistique de la Charente') proposed a classification for the Jurassic rocks of the Upper Charente, dividing the upper portion of the Jurassic rocks as follows:—

Upper Jurassic.

- Purbeckian.
- Portlandian.
    - Carious Limestone.
    - Limestone with *Nucula inflexa*.
    - Oolitic Limestone.
    - Limestone with *Cardium dissimile*.
    - Sands.
- Kimmeridgian.
    - Virgulian Marls.
    - Pterocerian Limestones.
    - Astartian Limestones.

Middle Jurassic.

- Corallian.
    - Oolite with *Nerinæa*.
    - Coral Limestone.
    - Solid Limestone.
- Oxfordian.
- Callovian.

Prof. Blake closely examined the distribution of the fossils and other characters in the beds of this and the following department, the Lower Charente, and satisfied himself of the presence of the Lower Portland and of beds representing the Purbeck.

The Department of the Lower Charente.—D'Orbigny in 1852, and Manès (' Statistique Géologique de la Charente Inférieure,' 1855) have studied the rocks of this department. Manès divides them into 4 groups:—

1. Portlandian......	280 feet	in 4	subdivisions.
2. Kimmeridgian...	260 „	in 2	„
3. Corallian.........	330 „	in 2	„
4. Oxfordian	550 „	in 2	„

Mr. Blake questions whether the rocks in the Lower Charente are different from those of the Upper. In the Rochelle district things are changed, and we are studying the development in a new basin; and, as the author states, we find that out of 222 Corallian species named by D'Orbigny in his ' Prodrome,' no fewer than 90, or more than 40 per cent., are peculiar, while only 80 occur in any of the localities yet studied. Here, again, I must refer to the careful study of these beds and their fossil contents by Mr. Blake.

III. Normandy with Orne-and-Sarthe.

In the department of the Orne-and-Sarthe the Upper Jurassic rocks are only feebly developed along the strip running from Le Mans in the south to Normandy. Hébert in 1857 (' Les mers anciennes et leur rivages dans le bassin de Paris. Part I. Terrain Jurassique ') showed the presence of his Middle and Upper Oxfordian beds, the former consisting of sands and calcareous grits with *Am. perarmatus* and *Am. cordatus*, the latter of marly beds with *Trigonia perlata* (*T. clavellata*), *Pholadomya decemcostata*, *Perna mytiloides*, and *Gervillia aviculoides*. Higher in the series are pisolitic beds with *Nerinœa*, and Diceras-beds with *Cardium corallinum* and *Corbis gigantea*, followed by marls and marly limestones of Kimmeridgian age with *Ostrea deltoidea*, *Trigonia Meriani* (" *muricata* "), *Rhynchonella inconstans*, &c.

Normandy.—This district should be studied on the coast; the sections there are complete, and afford the key to the interior. Caumont* in 1825–8, Hébert† in 1860, Dollfus‡ in 1863, and Lennier§ in 1870, have all described the several groups of rocks. Each of the above authors has divided or read them in their own way, and they give the following subdivisions founded on the sections examined by them:—

Caumont.	Hébert.	Dollfus.	
1. Kimmeridge Clay.	1. Coral Rag.	1. Ammonite-clays.	all Kimmeridgian.
2. Glos Sand and Blangy Limestone.	2. Upper Oxfordian.	2. Pteroceras-marls.	
3. Coral Rag.	3. Middle Oxfordain.	3. Trigonia - clays and limestones.	
4. Oxford Clay.			

* ' Explication de la Carte Géologique de Normandie,' 1825–8.

† " Du Terrain Jurassique supérieur sur les côtes de la Manche," Bull. Soc. Géol. France, sér. 2, vol. xvii. p. 300.

‡ ' La Faune Kimméridienne du cap de la Hève.'

§ ' Etudes Géologiques et Paléontologiques de la Haute Normandie.'

The coast section at Cap de la Hève presents an exact resemblance to the series at Weymouth and Osmington, "so close," observes Mr. Blake, "that almost bed for bed can be recognized; and the whole becomes, therefore, an admirable term of comparison between the French and English rocks, if only," as Mr. Blake suggests, "the development in each country could be correlated respectively with these." An elaborate analysis follows, in which the author discusses the affinities and differences between the faunas of the two countries (*loc. cit.* pp. 548–554).

IV. The Pays de Bray.

The early work of Graves upon this district ('Essai sur la Topographie Géognostique du département de l'Oise,' 1847) has been superseded by the splendid monograph of M. de Lapparent ('Le Pays de Bray,' 1879), published as one of the memoirs of the Geological Survey of France. M. de Lapparent's classification is as follows:—

Upper Portland.

Ferruginous Sandstone, Speckled Clays, Greensand.

Middle Portland.

Blue Marls.

Lower Portland.

1. Upper Conglomerate.
2. Glauconitic Calcareous Grit.
3. Marly Limestones.
4. Calcareous Grit with *Anomiæ.*
5. Beds with *Ostrea catalaunica.*

Kimmeridgian.

1. Upper Clays and Lumachelles.
2. Compact Lithographic Limestone.
3. Lower Clays and Lumachelles.
4. Calcareous Grit (Pterocerian or Astartian).

Prof. Blake has verified the accuracy of Lapparent's description and the general correctness of the correlation. Exceptions, in one or two instances, are taken and discussed by Mr. Blake (*loc. cit.* pp. 555–557).

V. The Boulonnais.

M. Rigaux in 1865, M. Hébert in 1866, and MM. de Loriol and Pellat, in five separate memoirs or monographs from 1866 to 1876, have largely contributed to the history of this remarkable area. M. Pellat, in 1878, gave a general and final summary of his views ('Résumé d'une description du terrain jurassique supérieur du Bas Boulonnais,' 1878). His classification is as follows (*loc. cit.* p. 558):—

1. Upper Portland in 4 divisions, yielding *Cardium dissimile, Natica elegans,* and *Cardium Pellati.*
2. Middle Portland in 2 divisions, yielding *Ostrea expansa* and *Cardium Morinicum.*

3. Lower Portland. Zone of *Cyprina Brongniarti* in 3 divisions, with *Pterocera oceani*, *Natica Marcousana*, and *Trigonia Pellati*.
3*a*. *Idem*. Zone of *Amm. gigas* in 2 divisions, with *Am. portlandicus* and *Hemicidaris purbeckensis*.
4. Upper Kimmeridgian. Zone of *Ammonites erinus* in 2 divisions, with *Am. erinus* and *Pygurus*.
5. Middle Kimmeridgian. Zone of *Amm. caletanus* in 2 divisions, the upper part with *Amm. caletanus*.
6. Lower Kimmeridgian. Zone of *Amm. orthoceras* in 2 divisions, upper part with *Amm. orthoceras*.
7. Sequanian, in 6 divisions, *Ost. deltoidea*, *Nerinæa*, and *Trigonia Bronnii*.
8. Corallian, Coral Rag, with *Cidaris florigemma*, and 3 divisions with *Isocardia* and *Terebratulæ*.
9. Upper Oxfordian in 2 divisions, with *Pseudodiadema heddingtonense* and *Amm. Martelli* and Sponges.
10. Middle Oxfordian in 2 divisions, with *Ostrea dilatata*.
11. Lower Oxfordian in 3 divisions, with *Ammonites Lamberti*, *Amm. Duncani*, and *Amm. calloviensis*.

These eleven divisions are discussed by Prof. Blake through pages 559 to 566. I cannot do more than refer to these eight pages, which teem with important correlative matter. From page 567 to 587 the author discusses the results of his investigations, and proposes to classify the rocks he has so carefully examined in the Paris basin under five heads :—

1. The Portlandian.

Upper = Purbeck.
Lower = Portland Limestone.

2. Bolonian.

Upper = Middle Portland.
Lower = Lower Portland.

3. Kimmeridgian.

Virgulian.
Pterocerian.
Astartian.

4. Corallian.

Supracoralline.
Coral Rag.
Coralline Oolite.

5. Oxfordian.

Upper = $\left\{\begin{array}{l}\text{Oxford Oolite.}\\ \text{Oxford Grit.}\end{array}\right.$
Lower = Oxford Clay.

Mr. Blake discusses the upper limit of the Oxfordian group; the French and English classifications do not agree. The English Lower Calcareous Grit and part of our Coralline Oolite are, in France, universally placed in the Oxfordian (*vide* pp. 567–570). He next describes the Corallian series and the relations of the English beds to those of France; pp. 570–577 are devoted to this division; pp. 577–580 and the remainder of this elaborate memoir conclude with the Bolonian and Portlandian rocks and their correlation.

Plate xxvi. exhibits 22 vertical comparative sections of the Upper Jurassic rocks of the Paris basin and England,—16 French, and 6 English. The French series commences with the Ardennes and finishes with the Boulonnais, through which every division discussed in the paper is shown. Those for England are Dorset, N. Wilts, Oxford and Bucks, Cambridge and Lincolnshire, S. Yorkshire and N. Yorkshire. The careful perusal of this table will show the nature and value of the paper contributed to the Society.

§ 3. Lias.

The division of the Lias of England into life-zones is of high importance; and of all the zoological groups that afford us reliable data for stratigraphical sequence, as indicated by organic remains, that of the Cephalopoda stands preeminent.

The tripartite division of the Lias of England is now admitted to be the true reading, whether physically or palæontologically considered, and each method confirms the other; the same law of succession and distribution holds good throughout Europe and, where known, in America. Taking as examples the magnificent sections on the Yorkshire and Dorsetshire coasts, the many localities and sections between, and the equivalent succession of strata in France and Germany, important generalizations are to be deduced. The division of the Lias into three stages is now an acknowledged fact throughout Europe; and these three stages are again subdivided into beds or zones which are characterized by certain species of Ammonites.

The Lower Lias is clearly divisible into seven well-defined horizons, or zones, characterized by as many species; reading upwards they are as follows:—

7. *Arietites (Ammonites) raricostatus*, Ziet.
6. *Amaltheus (Ammonites) oxynotus*, Quenst.
5. *Arietites (Ammonites) obtusus*, Sow.
4. *Arietites (Ammonites) Turneri*, Sow.
3. *Arietites (Ammonites) Bucklandi*, Sow.
2. *Ægoceras (Ammonites) angulatum*, Schloth.
1. *Ægoceras (Ammonites) planorbis*, Sow.

Below the last-named zone no Ammonite has yet occurred in the British Islands. *Ægoceras planorbis*, either in shales or hard limestones, rests immediately upon the Rhætic or *Avicula-contorta* series, with its ever accompanying bed containing remains of reptiles and fish, representing the close of the Triassic period or the Passage-beds between the Trias (Keuper) and Lower Lias.

Succeeding this, yet physically conformable, although differing lithologically and largely palæontologically, comes the middle division of the Lias or the "Middle Lias," a series of sandy, marly, and usually ferruginous limestones. This group of strata is also essentially characterized by Cephalopoda (Ammonites), certain forms of which hold restricted vertical ranges through this stage. We

recognize five zones in the Middle Lias, which stratigraphically succeed the zone of *Arietites raricostatus.*

The following six species of Ammonites are constant where the beds are fully developed, and constitute the recognized zonal forms, also reading upwards :—

6. *Amaltheus* (*Ammonites*) *spinatus*, Brug.
5. *Amaltheus* (*Ammonites*) *margaritatus,* Montf.
4. *Ægoceras* (*Ammonites*) *Henleyi*, Sow.
3. *Amaltheus* (*Ammonites*) *ibex*, Quenst.
2. *Ægoceras* (*Ammonites*) *Jamesoni*, Sow.
1. *Ægoceras* (*Ammonites*) *armatum*.

Associated with these species there also occurs an assemblage of species of other Mollusca which at once distinguishes the Middle from the Lower and Upper Lias.

The clays, shales, and sands of the Upper Lias, when occurring in a complete section, are divided into eleven well-defined and recognizable zones. The sandy or upper portion of this stage, the Upper Lias sands, or "Midford Sands"*, are chiefly characterized by the two groups *Harpoceras* and *Lytoceras*.

In Gloucestershire and Somersetshire they include six zones, characterized by

6. *Harpoceras* (*Ammonites*) *opalinum*, Rein.
5. *Harpoceras* (*Ammonites*) *radians*, Schloth.
4. *Harpoceras* (*Ammonites*) *Thouarsense*, d'Orb.
3. *Harpoceras* (*Ammonites*) *insigne,* Schübl.
2. *Lytoceras* (*Ammonites*) *jurense*, Ziet.
1. *Lytoceras* (*Ammonites*) *hircinum*, Schübl.

The lower portion of the Upper Lias, consisting of clays varying in consistency and colour (black in Yorkshire, dark grey in the Midland counties, and pale grey or pale brown in Somersetshire and Dorsetshire), is everywhere distinguished by

5. *Harpoceras* (*Ammonites*) *bifrons*, Brug.
4. *Harpoceras* (*Ammonites*) *serpentinum*, Schloth.
3. *Stephanoceras* (*Ammonites*) *commune*, Sow.
2. *Stephanoceras* (*Ammonites*) *anguinum*, Rein.
1. *Stephanoceras* (*Ammonites*) *fibulatum*, Sow.

The grand cliff sections of the Yorkshire coast exhibit almost every zone in all three of the above divisions, except those of *Ægoceras angulatum* and *Æ. planorbis*, both of which are concealed beneath the German Ocean at Robin Hood's Bay and at Redcar, although in both localities the beds occur.

Probably the most complete continuous section in Europe is comprised in the succession exhibited along the Dorsetshire coast from Pinhay Bay, west of Lyme Regis, to Burton Bradstock, east of Bridport Harbour. The shore west of Lyme Regis, Black Ven near Lyme, and Charmouth, Westhay, Golden Cap, Eype Down, &c. are,

* Phillips, 'Geol. of Oxford and Thames Valley,' p. 118 (1871).

indeed, classical localities for clear demonstration of the succession of the Ammonite zones of the entire Lias formation.

"This coast section may be said to be complete from the great arenaceous deposit of Upper Lias sand, containing *Harpoceras opalinum*, with each succeeding zone of the Upper, Middle, and Lower Lias, down to *Ægoceras planorbis*, and its *Ostrea* series [*O. liassica*] resting on the *Avicula-contorta* beds of the Trias" near Axmouth *.

Rhætic or Avicula-contorta *Beds*, Portlock, 1843.

Kössener Schichten, *Von Hauer*, 1853.
Oberes St. Cassian, *Escher*, 1853.
Gervillien- (Kössener) Schichten, *Gümbel*, 1856.
Die Zone der Avicula contorta, *Oppel*, 1859.
Infra-Lias du département de la Côte d'Or, *Jules Martin*, 1860.

These and numerous other names constitute the synonymy of the *Avicula-contorta* zone, a name given by Col. Portlock in 1843 to beds in the N. of Ireland containing the shells *Avicula contorta* and *Pecten valoniensis*. This series was then believed to belong to the Lower Lias, and for many years this view was held; but the progress of research into the history and structure of the Rhætian Alps and their palæontological contents resulted in clearly determining that the fauna of the *Avicula-contorta* or Rhætic beds belonged to the Triassic rather than to the Liassic group, especially as exemplified by the Fishes and Reptilia; and there cannot be any doubt that the fauna of the *Avicula-contorta* zone has closer affinities with that of the Kössener Schichten of the Tyrol and the Upper St.-Cassian beds of Germany (Escher) than with the Lias, from the fact that most of the species found in the Rhætic beds do not pass into the Lower Lias. The chief species of Mollusca are *Cardiam rhæticum*, *Pecten valoniensis*, *Neoschizodus*, *Pleurophorus*, *Avicula contorta*, and *Schizodus angulatus* (*Myophoria*). Fishes: *Nemacanthus*, *Acrolepis*, *Sargodon*, *Saurichthys*, *Gyrolepis*, *Ceratodus*, &c. The Reptilia of the genera *Ichthyosaurus* and *Plesiosaurus* are here first known, but with species differing from those of the Lower Lias. The earliest mammal known (*Microlestes antiquus*) occurs in the Rhætic beds of this country as well as in those at Dierloch, in Württemberg. From Redcar in Yorkshire to Lyme Regis in Dorsetshire we obtain the *Avicula-contorta* beds wherever the junction of the Trias and Lias is revealed; and they retain their physical and palæontological characters throughout, consisting of black pyritous shales and thin impure limestones crowded with ill-preserved shells.

On the continent of Europe this Rhætic or *Avicula-contorta* zone has also a most extensive geographical range. Its deposits are met with in Germany, Switzerland, France, Hungary, and as far north as Sweden. We find them in Württemberg, near Tübingen, Stuttgart, and Göttingen; in Baden, at Bamberg and Baireuth; near Bruns-

* Dr. Wright, Palæontographical Soc. vol. xxxii., Monogr. Lias Ammonites, p. 2 (1878).

wick, Hildesheim and Hanover. The Vaudois Alps, the Canton of Aargau, and near Basel are localities in Switzerland.

The Côte d'Or, Aveyron, Herault, Luxembourg, and Belgium possess this transition group in greater or less development; it varies in thickness from 40 to 3000 feet throughout its distribution in Spain. The most complete sections in England are to be studied at Aust Passage and Garden Cliff, Westbury (Gloucestershire), Penarth Cliff (Glamorganshire), and St. Audrey's slip (Somersetshire); nowhere do they exceed 50 feet in thickness, but lithologically and palæontologically they are the same throughout.

It is difficult to arrive at the true number of species in the Rhætic zones of Britain; they are a group not easily studied and difficult to obtain. Our knowledge of the fauna is incomplete, owing to the physical structure or fissile and shaly nature of the beds, no limestone of appreciable and constant thickness occurring in the series; as near as I can tell, we possess 54 genera and 100 species, which may be tabulated as follows:—

	Genera.	Species.
Plantæ	2 or 3	3
Asteroidea	1	1
Crustacea	3	3
Brachiopoda ..	1	1
Monomyaria ..	9	15
Dimyaria	13	25
Gasteropoda ..	8	17
Cephalopoda ..	none	none
Pisces	12	27*
Reptilia	2	4
Mammalia	2	4
	54	100

In the famous sections of Aust Passage, Westbury or Garden Cliff, Wainlode, &c., fifty species have been collected. In the cliffs near Penarth, probably the most complete section in Britain, nearly every known British species has been obtained. This section is especially rich in the Mollusca, of which fifteen species occur, and ten species of fish; at Barrow on Soar the complete series was cut through; and the railway-cutting at Elton, near Nottingham, exhibited the series in conjunction with the Gypsiferous Marls below. As far north as Gainsborough they have been continuously traced wherever the two series have been seen in position. The generalizations deducible from the deposition of the British Rhætics, and what we now know concerning the great series in Europe, are numerous and important. It is doubtful if any other series affords more scope for speculation as to its deposition and accumulation, especially when we know that we have not in the British Islands, in one section (or all united), a complete or even representative series of these

* Assuming that there are 19 species of *Ceratodus*.

strata that can be coordinated with the deposits commencing with the Muschelkalk, which in time, though not in condition, paralleled our Bunter and Keuper deposits. These thick strata, either of freshwater or marine origin and almost devoid of life, stand alone. Their final close through elevation within the British area gave us a series of deposits known as the Rhætic series of Middle and Eastern Europe. Continental changes alone can only account for our not possessing the Muschelkalk, the St.-Cassian or Hallstatt beds, the Dachstein, Kössen or Upper St.-Cassian beds of Switzerland, and other groups occurring in the typical area of Europe.

The nature of the fauna is suggestive of geographical rather than climatal changes, the species being developed either in shallow, estuarine, or brackish waters, consequently dwarfed and stunted in growth; and although we possess many of the European forms, there is yet, in those regions where the series are fully developed, a fauna the magnitude of which is nearly unequalled by any British deposit.

No less than 281 genera and 1830 species are known to occur in the whole of the three divisions of the Lias of Great Britain and Ireland. These extend through 16 classes, not including the kingdom Plantæ, which is represented in the Lias by 12 genera and 17 species, 11 genera and 15 species occurring in the Lower Lias, and 1 genus and 2 species (*Peuce Huttoniana* and *P. Lindleyana*) in the Upper Lias. No species is known in the Middle Lias; here and there fragments of wood occur, but no determinable form has yet been detected. The Plantæ of the whole series of the British Jurassic rocks number 63 genera and 191 species, 130 of which belong to the Inferior Oolite, mostly from the Yorkshire beds. Few or none occur in the continuous strike of the Lower Oolitic series, from Whitby through the mid-eastern part of England and on to Lyme Regis and Portland. True it is that the estuarine and terrestrial beds so finely shown along the Yorkshire coast are only to be examined in detached portions in Lincolnshire, Northamptonshire, &c. The above general considerations lead me to discuss the fauna and flora of the Lower, Middle, and Upper Lias, or the Lias as a whole as compared with the succeeding Middle and Upper Jurassic series.

Plantæ: *Lower Lias.*—The Coniferæ and Cycadeæ predominate in the Lower Lias; 9 of the 12 genera and 11 of the species that occur belong to these two families. *Sphærococcites* may be an alga. *Naidites* is represented by 3 species; *Equisetites* by 1 (*E. Brodiei*); *Otozamites* by 1 species, but this genus greatly predominates in the Inferior Oolite. The two Coniferæ in the Upper Lias are *Peuce Huttoniana* and *P. Lindleyana*; no species of this genus passes to any higher horizon. I am not aware of any species out of the known 192 occurring in the Jurassic rocks that range from a lower to a higher horizon, or pass to any higher beds throughout the whole of the Jurassic series.

Middle Lias.—No described or recognized species of plant is known to occur in the Middle Lias. Both in Yorkshire and in Dorsetshire,

where this division of the Lias is greatly developed, no species has as yet been determined.

Upper Lias.—One genus (*Peuce*) with 2 species, *P. Huttoniana* and *P. Lindleyana*, are all the plant-remains known in the Upper Lias. We have no evidence of estuarine or true land conditions in the Upper Lias of any area in Britain, although the succeeding sandstones and shales of the Inferior Oolite in Yorkshire were evidently deposited in shallow water and contiguous to land on which flourished a luxuriant vegetation. Remains of true marine plants appear to be unknown in the Lias, and only sparingly occur in the succeeding Oolites. We should rather expect to find evidence of moderately deep-water Algæ in both the Lower and Upper Lias, the character of the clays being such as to preserve delicate tissues or organisms.

AMORPHOZOA (*Spongida*).—The only genus known (*Grantia*) belongs to the Calcispongiæ. The Great Oolite is the only horizon where the Amorphozoa predominate; we there find 9 out of the 11 known Jurassic species; these are noticed under the horizon in which they occur.

RHIZOPODA (*Foraminifera*).—Recent research into the history and distribution of the Secondary and Tertiary Rhizopoda has greatly added to the number of known species. In the Lias alone there are 23 genera and 100 species; 17 of these are Triassic also. 84 of the 100 occur in the Lower Lias, the more important genera being *Cristellaria*, *Dentalina*, *Marginulina*, *Frondicularia*, *Polymorphina*, and *Planularia*; the species belonging to these 6 genera number 56, the remaining 17 genera having few representatives, namely 30 in all. 36 of the 84 species pass to the Middle Lias, or are common to the Lower and Middle divisions. 20 species appear in all three divisions of the Lias, and 9 in the Lower and Upper divisions only. No species probably passes to higher strata, although our lists record forms of *Dentalina* (*D. communis*) as common to the Coral Rag, Kimmeridge, and Lias. So also with *Marginulina* and *Polymorphina*; but these are probably doubtful determinations, as they do not appear to occur between. Our exact knowledge of the structure and distribution of the Liassic species is due to the elaborate researches of H. B. Brady, Esq., F.R.S., and the industrious collecting of Messrs. Tate and Blake, as recorded in their valuable work on the Lias of Yorkshire; to Dr. Carpenter, W. K. Parker, Esq., and Prof. Rupert Jones we are also deeply indebted for their exhaustive researches into foraminiferal zoology. D'Orbigny, Reuss, Bornem, Terquem, Römer, and others have greatly added to the literature and history of these deep-sea forms of life; and the late explorations of the 'Challenger' have shown us the value of paying close attention to the minute zoology of the sea-bed and its significance in enabling us to determine the history of the Foraminifera and Spongida through space and time. Their time-history is a subject of the highest interest and importance stratigraphically. The Dactyloporidæ range from the Trias to the seas of today; the genus *Gyropella* constitutes vast masses of limestone in the Trias of the Bavarian and Tyrolese Alps; *Lituola*

and *Endothyra* range from the Carboniferous rocks to the present day, and, like *Gyropella*, form entire beds of limestone. The remarkable Carboniferous genus *Saccammina* also forms entire beds of limestone in the Carboniferous rocks of the South of Scotland and the North of England, yet from that time, through all the newer deposits, down to the Postpliocene and recent periods it has never occurred*. The colossal and complicated genus *Parkeria* from the Cretaceous rocks (Upper Greensand) of Britain, and the fusiform *Loftusia* of Eocene age from Persia, the *Miliolæ* which constitute the Eocene Miliolite Limestone of the Paris basin, and which commenced in the Lias, are examples of the Imperforata that have played an important part in the seas of the globe, and in the construction of the rocks in which they occur. The second suborder, the Perforata, or those having hyaline or vitreous calcareous shells, illustrated by the Lagenida, Globigerinida, and Nummulinida, abound in the Trias and Lias.

The most important genera, or those possessing most species, are *Cristellaria* represented by 12 species, *Dentalina* 17, *Marginulina* 9, *Planularia* 8, *Polymorphina* 11, *Frondicularia* 7, *Nodosaria* 7. 7 of the 23 genera have only 1 species; 3 have 2 species.

84 species occur in the Lower Lias, 48 in the Middle, and 33 in the Upper Lias. The succeeding 6 stages or horizons possess none; only 3 species occur in the Oxford Clay, 1 in the Coral Rag, and 13 in the Kimmeridge Clay. This unequal distribution cannot be accounted for on zoological grounds only; did they occur between the Upper Lias and the Kellaways Rock in Britain, we should have observed them; all evidence tends the other way. 10 genera and 17 species appear to be common to the Trias (Keuper marls) and Lias, chiefly Lower Lias. None occur in the intermediate Rhætic beds, so far as we know.

CŒLENTERATA. *Hydrozoa.*—I am not aware that any species of this class occur in the Jurassic rocks of Britain. The subclass Discophora, through the order Medusidæ, and the subclass Lucernarida, through the *Rhizostomidæ*, are represented in Jurassic rocks on the continent; the Medusidæ, through members of the existing families *Æquoridæ* and *Trachymenidæ*, have left their impressions in the highly levigated lithographic stone of Solenhofen (Kimmeridge); and the genus *Hexarhizites* of the *Rhizostomidæ* represents the Lucernarida in the corresponding remarkable deposits at Pappenheim and Eichstadt. Doubtless this class was abundantly represented in the seas of the Lias and those which laid down the higher Jurassic rocks in Britain; but the delicacy of their tissues and their possessing no hard skeleton or structure, and there being no deposit, save the "white Lias" at the base of that formation, which could have preserved such delicate organisms, would stand in the way of their being recognized.

Actinozoa.—17 genera and 80 species have been described from the Lias; 13 genera and 72 species from the Lower Lias; 6 genera

* We have here a remarkable instance of the continuity of a genus from the Carboniferous period, but which has never been recognized in intermediate strata.

and 8 species from the Middle; and 2 genera and 2 species from the Upper Lias. Only 1 of the 72 Lower Lias species (*Montlivaltia excavata*) passes to the Middle Lias; it is questionable if *Lepidophyllia hebridensis* is both Lower and Upper Lias; and I even doubt if *Montlivaltia excavata* above mentioned really occurs in the Middle Lias; should this be so, no single form passes from the Lower Lias to higher beds, the 8 Middle Lias species being quite distinct. The genera represented by the largest number of species are *Astrocœnia* (14 species), *Isastræa* (7), *Montlivaltia* (20), *Septastræa* (4), *and Thecosmilia* (14 species). 4 genera are recognized by a single species each, viz. ? *Cyathophyllum novum*, *Latomœandra denticulata*, *Oppelismilia germinans*, and *Rhabdophyllia recondita*; *Elyastræa* and *Thecocyathus* have only 2 representatives each, *E. Fischeri* and *E. Moorei*, and *T. rugosus* and *T. Moorei*; I name these because of their rarity, and to show that the paucity of species is probably due to want of research. The preponderance of species in the genus *Montlivaltia* in the British Jurassic rocks is greater than that of any other genus of corals; no less than 43 species are known; 21 occur in the Lower, 3 in the Middle, and 1 in the Upper Lias; 11 species occur in the Inferior Oolite, 3 in the Fuller's earth, 3 in the Great Oolite, and 1 in the Coral Rag (*M. dispar*). Of the genus *Astrocœnia*, out of the 14 species known, no less than 13 belong to the Lower Lias; and *Thecosmilia* is in much the same case, for out of the 19 species catalogued 14 are also Lower Lias. 3 genera, with only a single species in each, occur in the Middle Lias; and I believe only 2 genera and 2 species are known in the Upper Lias; they are *Montlivaltia tuberculata* and *Trochocyathus primus*.

No Actinozoa (Aporosa) occur in either of the 3 divisions of the Lias of Yorkshire; and the same may be said of Dorsetshire. There scarcely appears any physical reason why such should be the case, unless the Lias of the north and south of England was accumulated under deep-sea conditions or under depression, conditions unsuitable to coral growth; whilst the more central portions of England, now Warwickshire, Oxfordshire, Northamptonshire, &c., were probably rising or stationary, giving time for the coral fauna to be developed. Certainly most of the Lower and Middle series of the Jurassic rocks were deposited in moderately shallow water. In Yorkshire, from the Dogger upwards to the Kellaways Rock, or the base of the Oxfordian group, this was certainly the case; and in Northamptonshire the same. All the Jurassic rocks of Yorkshire only yield 12 species, 3 in the Lower and 9 in the Middle Oolite.

Middle Lias.—Astrocœnia Oppelii, *Cyclolites cupuliformis*, *Lepidophyllia hebridensis*, *Montlivaltia foliacea*, *M. Victoriæ*, *M. excavata*, *Thamnastræa Etheridgii*, and *Tricycloseris Anninigiæ* are the only Actinozoa known in the Middle Lias; their geographical distribution is as varied as the species are few. The following Table (XVIII.) will show their distribution :—

Table XVIII.

	King's Sutton.	Banbury.	Cherring-ton	Charmouth.	Lyme Regis.	Hebrides.
Astrocœnia Oppelii	...	...	...	...	*	
Cyclolites cupuliformis ...	*					
Lepidophyllia hebridensis .	...	...	...	...	...	*
Montlivaltia foliacea.........	...	...	*	*		
—— Victoriæ	...	*	*	*		
—— excavata	...	...	...	*		
Thamnastræa Etheridgii...	*	*	*			
Tricycloceris Anningiæ ...	...	...	...	...	*	
Total	2	2	3	3	2	1

The Middle Lias, although so well developed in England, especially in Yorkshire and the extreme south of England at Lyme Regis, contains few or no corals in any of the zones, of which 5 are readily distinguished; in ascending order they are the zones of:—1st, *Ægoceras Jamesoni*; 2nd, *Amaltheus ibex*; 3rd, *Ægoceras Henleyi*; 4th, *Amaltheus margaritatus*; and 5th, *Amaltheus spinatus*, above which conformably rests the Upper Lias. This is not, however, the place to fully discuss the fauna of these zones. That of the zone of *Ægoceras Jamesoni* is large and remarkable, including no less than 15 species of Ammonites and 24 species of Belemnites, 12 genera and 28 species of Gasteropoda, 31 genera and 63 species of Lamellibranchiata, 16 species of Brachiopoda, 7 genera and 9 species of Crustacea, 9 species of Annelida, 5 genera and 8 species of Echinodermata, and 14 genera of Foraminifera with 48 species. Oxfordshire, Somersetshire, Dorsetshire, Yorkshire, with Pabba, Scalpa, Skye, Raasay, and the Hebrides, show the wide distribution of the zone of *Am. Jamesoni*. The fossils from this zone of the Hebridean Jura have been carefully studied by Dr. Wright, F.R.S.† They are essentially the same as those of mid-England, Yorkshire, or Dorsetshire. In Somersetshire all three zones of *Jamesoni*, *ibex*, and *Henleyi* have so thinned away as to be comprised in 9 feet of strata; but even in this insignificant thickness there occur 12 species of Ammonites, 10 genera and 18 species of Gasteropoda, 21 genera and 28 species of Lamellibranchiata, and 6 genera and 14 species of Brachiopoda.

Foreign Equivalents or correlation.—North and South Germany possess this extensive zone of the Middle Lias; it is the equivalent of the Numismalis Marl of Swabia. The ironstone beds worked

† "Notes on the Fossil Collection, by Mr. Geikie, from the Lias of the Isles of Pabba, Scalpa, and Skye," Quart. Journ. Geol. Soc. vol. xiv. p. 24 (1858).

at Harsburg, Liebenburg, Bodenstein, &c., are on this horizon. At the foot of the Swabian Alps, in South-western Germany, the Numismalis-Marls contain the type fossils of the British equivalents. In France the Jamesoni-beds occur, and are well developed in several of the departments. In Normandy Deslongchamps includes them in the 'Calcaires et Marnes à *Terebratula numismalis.*' In the Côte d'Or Collenot describes the Jamesoni-beds, and divides the Middle Lias into 4 zones, according to the prevailing Ammonites, in descending order:—

The zone of *Ægoceras Henleyi*;
The zone of *Ægoceras Davœi*;
The zone of *Ægoceras venarense*;
The zone of *Ægoceras Valdani*.

In the departments of the Cher and Aveyron *Lytoceras fimbriatum*, *Amaltheus margaritatus*, and *Ægoceras Jamesoni* hold their respective positions. In the department and basin of the Rhone, Dumortier shows the extensive development of this division, and divides the Middle Lias of the Rhone basin into two great zones, the lower division being that of *Belemnites clavatus*, the upper that of *Pecten æquivalvis*.

Zone of *Amaltheus ibex*.—The beds containing this Ammonite and some 8 or 10 other species long ago occupied the attention of De la Beche and Murchison; they are the Upper Marls (in part) of De la Beche, occurring at Golden Cap and Black-Ven, at Lyme Regis*.

Sir Roderick Murchison, in 1845, with Prof. Buckman (Geol. of Cheltenham, 2nd ed. p. 42) recognized and described these beds, which were then exposed at Battle Down, near Cheltenham, Leckhampton, Churchdown, and Dumbleton. The tenacious yellow clays and hard ferruginous nodules distributed through the series of beds yield numerous Mollusca; amongst them *Amaltheus ibex*, *Ægoceras Valdani*, *Æ. Maugenesti*, *Lytoceras fimbriatum*, and *Phylloceras Loscombi* are conspicuous and well known. The highly typical *Cardinia attenuata* abounds in the ferruginous nodules, with *Arca truncata* and *A. elongata*, and associated with *Rhynchonella furcillata*, *R. rimosa*, and *Pecten priscus*. I know of no Actinozoa from this zone.

The most exhaustive notice and description of the Ibex-series is that prepared by Mr. E. B. Tawney, M.A., in his paper upon the "Lias of the neighbourhood of Radstock"†. His memoir is of great value as tending to clearly and definitely fix the position of the Munger beds near Radstock.

The general persistency of the Ibex-clays and limestones above those containing *Ægoceras Jamesoni* is thus maintained, although the latter is found associated by Mr. Tawney at Munger with *Æ. Maugenesti*, *Æ. Valdani*, *Lytoceras fimbriatum*, &c. This gives to *Æ. Jamesoni* a long range in time.

* De la Beche, "Lias of Lyme Regis," Geol. Trans. 2nd ser. vol. ii. p. 22, 1823.

† Proceedings Bristol Nat. Soc. vol. i. p. 178 (1875).

In Dorsetshire it occurs below the Davæi series. Oppel, in his 'Die Juraformation: die Schichten des Ammonites Ibex,' p. 122, and Wright, "Ibex-bed" (Quart. Journ. Geol. Soc. vol. xiv. p. 25), in his table, shows the correlation of the beds on the continent with those of Gloucestershire and Scotland (Skye).

Upper Lias.—Only two species of Actinozoa have as yet been detected in the Upper Lias of the British Islands; they are *Montlivaltia tuberculata* and *Trochocyathus primus*. The last-named is from the Ilminster beds; and *Montlivaltia tuberculata* occurs at Adderbury, near Banbury.

The Actinozoa of the Lias therefore essentially belong to the lower division and to the lowest zones. The zones of *Ægoceras planorbis*, *Æ. angulatum*, *Arietites Bucklandi*, *A. Turneri*, *A. raricostatus*, and *Ægoceras Jamesoni* yield most of the 72 Lower-Lias species known. No Tabulata or Perforata have as yet been discovered; and although the Rugosa (fam. Stauridæ) have occurred in a single instance in the Upper Secondary rocks (Upper Neocomian), yet neither in the Liassic nor Oolitic series have any been detected. *Holocystis elegans* therefore is the only true compound representative of the *rugose* Corals above the Carboniferous Limestone. (Species are said to occur in the Tertiary beds and living; this may require confirmation.)

Prof. P. Martin Duncan, F.R.S., has, however, shown that the majority of the Corals of the lowest members of the Lias are peculiarized by the imperfection of their septal arrangement; the distinct development of definite cycles in six systems is rarely observed; and it would appear that this high organization was not attained in the forms which had varied from Palæozoic into Mesozoic species*.

The remarkable section at Dunraven, in Glamorganshire, where the Sutton Stone is exposed, has yielded corals which Laube has described as occurring in the St. Cassian beds of the Trias; they are *Thecosmilia rugosa*, *Rhabdophyllia recondita*, and *Elyastræa Fischeri*. The occurrence of these species in the zone of *Ægoceras angulatum* of the Infra Lias is significant and interesting.

The genera which are represented in the zones of *Ægoceras planorbis* and *Ægoceras angulatum* are *Montlivaltia*, *Rhabdophyllia*, *Thecosmilia*, *Oppelismilia*, *Isastræa*, *Astrocœnia*, *Cyathocœnia*, *Elyastræa*, *Septastræa*, and *Latomæandra*.

The luxuriance of the species in the above zone in South Wales and one or two other localities shows that the Lias is not the uncoralliferous formation it was once believed to be; and each of the succeeding recognized Ammonite zones has a distinct specific coral-fauna. The following Table (XIX.) illustrates the distribution of the Actinozoa in the zone of *Ægoceras angulatum*.

* Monog. Brit. Foss. Corals, 2nd ser., Palæontographical Society, pt. 4. no 1.

TABLE XIX.

British and Continental Species of Corals in the Zone of *Ægoceras angulatum.*	No. of species.	South Wales.	Ireland.	France.	Luxembourg.	St. Cassian.	Scotland.	England.
Oppelismilia	1	...	1					
Montlivaltia	13	7	3	8	2	...	...	3
Thecosmilia	12	11	...	3	1	1	...	1
Rhabdophyllia	1	1	...	...	...	1		
Astrocœnia	12	12	...	2				
Cyathocœnia	3	3						
Elyastræa	2	2	...	...	...	1		
Latomæandra	1	1						
Isastræa	4	2	...	...	...	...	1	1
Total	49	39	4	13	3	3	1	5

Only 7 species are known in the zone of *Arietites Bucklandi,* and the same 7 occur also in the Angulatum-beds below; otherwise the faunas of the two zones differ essentially. These 7 corals are *Montlivaltia Guettardi*, *Septastræa eveshami*, *Lepidophyllia Stricklandi*, *Isastræa endothecata*, *I. insignis*, *I. Stricklandi*, and *Cyathocœnia globosa.* The preponderance of Cephalopoda in these beds is a marked feature, especially at Lyme Regis, where the Bucklandi-beds are nearly 100 feet in thickness. The same horizon in Yorkshire, at Robin Hood's Bay and Redcar, is hidden or covered at high water, and ranges under the German Ocean. The Côte d'Or in France exhibits these Bucklandi-beds with a rich fauna, no less than 52 species of Ammonites alone occurring therein.

No corals are known in the Turneri-beds, and only 2 species appear to have come from the Obtusus-Shales and Limestone bands, although physically the zone is thick, being nearly 100 feet. Many genera of fish and Saurians occur in the Obtusus-series at Lyme Regis. In North and South Germany and France the species are the same as those of Britain.

No Actinozoa have been detected in the zone of *Amaltheus oxynotus,* either at Lyme Regis or Cheltenham, or at Robin Hood's Bay in Yorkshire.

The succeeding series of shales and clays, composing the *Arietites-raricostatus* zone, have yielded 4 species, viz. *Montlivaltia rugosa*, *M. mucronata*, *M. radiata*, and *M. nummiformis.* In the vale of Glou-

cester, at Honeybourne in Warwickshire, at Lyme Regis, and at Robin Hood's Bay we have the same lithological conditions, chiefly comprising dark pyritous shales, the absence of limestones being a marked feature.

The coral fauna of the *Ægoceras-angulatum*, or Infra-Lias, beds, we have seen, numbered nearly 50 species; but the total number of species known in the succeeding 6 zones is only 13: 6 of these are *Montlivaltiæ* and 4 *Isastrææ*, *Septastræa*, *Lepidophyllia*, and *Cyathocœnia* having only one species each.

No coral fauna occurs in the zone of *Ægoceras Henleyi*, or in those of *Amaltheus margaritatus* and *A. spinatus*, although all three groups of strata characterized by these three species are completely developed in England, especially the two last named. I shall have occasion to notice these zones in detail in my remarks upon the distribution of the Cephalopoda; it is essential, however, to notice them here under the Lias for the purpose of illustrating the distribution of the Actinozoa.

Four of the zones into which the Upper Lias can be readily divided—viz. the zones of *Harpoceras serpentinum*, *H. bifrons*, *Lytoceras jurense*, and *Harp. opalinum*—contain only two species of corals throughout their known range; as before stated, these are *Montlivaltia tuberculata* and *Trochocyathus primus**. The dark clays and sandy beds in Yorkshire, with *Stephanoceras commune*, *Harpoceras falciferum*, *Stephanoceras crassum*, *Harpoceras elegans*, and many others, are rich in all groups but the Cœlenterata.

The coral fauna then of the 3 divisions of the Lias is a singular illustration of stratigraphical distribution and physical conditions: the Lower Lias, and chiefly the lowest zones of the group, have yielded 72 species representing 13 genera; the Middle Lias only 8 species belonging to 6 genera; and the Upper Lias 2 genera and 2 species. We have no reason to suppose that many other species occur; though, looking at the development of the Upper Lias, laterally and vertically, in Britain, they may be expected to be more abundant: be it remembered that the seas of Britain at present contain but one or two species, and their habitats are not congenial for preservation.

ECHINODERMATA.—The Jurassic rocks of the British Islands are known, up to the present time, to contain 47 genera and 216 species; the Lias, in all the three divisions, 20 genera and 53 species. In the Lower Lias 11 genera and 15 species occur; in the Middle 14 genera and 29 species; and in the Upper 8 genera and 14 species. Few species occur in any of the Lias genera of Echinodermata except *Pentacrinus*, of which 2 occur in the Lower, 9 in the Middle, and 6 in the Upper Lias; with this exception, no genus in either of the three divisions is represented by more than 5 species, the number possessed by *Ophioderma*. The remaining 10 genera are very sparingly represented.

* *Trochocyathus Moorei* is a doubtful species.

In the Lower Lias :—

Acrosalenia ..	possesses	2	species.
Apiocrinus ..	,,	1	,,
Cidaris	,,	1	,,
Extracrinus ..	,,	1	,,
Hemipedina..	,,	1	,,
Ophiolepis ..	,,	1	,,
Pentacrinus ..	,,	2	,,
Plicatocrinus .	,,	1	,,
Plumaster ..	,,	1	,,
Pseudodiadema	,,	1	,,
		12	,,

The Middle Lias presents similar results :—

Acroura	yields	1	species.
Aspidura	,,	1	,,
Astropecten ..	,,	2	,,
Cidaris	,,	1	,,
Extracrinus ..	,,	1	,,
Hemipedina ..	,,	1	,,
Ophiolepis ..	,,	1	,,
Pentacrinus ..	,,	9	,,
Plumaster ...	,,	1	,,
Pseudodiadema	,,	1	,,
Rhabdocrinus .	,,	1	,,
Tropidaster ..	,,	1	,,
Uraster	,,	2	,,
Ophioderma ..	,,	5	,,
		28	,,

The Upper Lias possesses a much smaller fauna, and no species passes from either of the three divisions of the Lias to any higher horizon; the succeeding beds of the Inferior Oolite contain 33 species, all totally new. The Upper Lias genera and their specific value is expressed as before :—

Acrosalenia ..	has yielded	1	species.
Cidaris	,,	2	,,
Diplocidaris ..	,,	1	,,
Hemipedina ..	,,	1	,,
Ophioderma ..	,,	1	,,
Pentacrinus ..	,,	6	,,
Pseudodiadema	,,	2	,,
		14	,,

No Palæozoic form lived on into the sea of the Lias. The one single genus known in the Permian rocks, *Archæocidaris*, modified through descent from the Carboniferous Limestone and Permian rocks, may perhaps have been the progenitor of the Cidaridæ of the Lias; no other type of the Echinoidea has been transmitted. The

Crinoidea, so abundant in the Carboniferous seas, are represented in the Lias by *Rhabdocrinus*, *Extracrinus*, and *Pentacrinus*, the older Palæozoic forms disappearing in the Permian rocks. No form of irregular Echinoidea (*Echinoidea exocyclica*) has yet been detected in either of the three divisions of the Lias. They first appear in the lowest bed of the Inferior Oolite, and are there individually very abundant.

Lower Lias.—The lowest beds of the Lias (the zone of *Ægoceras planorbis*) yield at Lyme Regis and other localities *Cidaris Edwardsii*, *Pseudodiadema lobatum*, *Hemipedina Bechei*, *H. Bowerbankii*, and *H. Tomesii*.

The zone of *Ægoceras angulatum* has also yielded *Cidaris Edwardsii* and *Hemipedina Tomesii*, together with *Pentacrinus psilonoti* and *P. basaltiformis*. In Yorkshire, Dorsetshire, and Warwickshire this zone yields a remarkable and prolific fauna, especially of Gasteropoda and Lamellibranchiata. Messrs. Tate and Blake, in their 'Yorkshire Lias,' exhaustively detail the history of this zone in Yorkshire. Prof. Tate, in 1867 (Q. J. Geol. Soc. vol. xxiii.), described the Lower Lias of the north-east of Ireland, both the zone of *Ægoceras planorbis* and that of *Belemnites acutus*, and also the fossiliferous zone of *Æ. angulatum*. From eight localities he gives a list of 102 species. The researches of Jules Martin in the Angulatum-beds of the Côte d'Or, and those of MM. Terquem and Piette, in the "Lias Inférieur de l'est de la France" (Mém. de la Soc. Géolog. de France, 2 sér. tome viii. p. 1), have greatly advanced our critical knowledge of these lower divisions of the Lias of France, and thrown much light upon the history of the English deposits of the same age. In Yorkshire alone nearly 120 species occur in this zone, 50 of which are Lamellibranchs and 27 Gasteropods, with 5 species of Ammonites, *A. Conybeari* and *A. Johnstoni* being amongst them. Some species pass to the succeeding Bucklandi-beds, but not sufficient to allow of any union of the two zones. No species in any genera occurring in the Lias pass to the Inferior Oolite or higher beds. In the Bucklandi-series no new forms have been detected, either in France or England. One only, *Acrosalenia minuta*, is added to the fauna of the Oxynotus-series. The same species, with *Pentacrinus scalaris* and *P. psilonoti*, pass to the zone of *Arietites raricostatus*.

Middle Lias.—The rich and prolific horizon of *Ægoceras Jamesoni* includes *Ophioderma Gaveyi*, *Pentacrinus Milleri*, *Pseudodiadema* (?), *Plumaster ophiuroides*, *Extracrinus subangularis*, *Millericrinus Hausmanni*, *Pentacrinus punctifer*, *P. robustus*, and *P. lævis*.

Both in the north and south of England the Capricornus-clays and limestones, which succeed everywhere the Jamesoni-series, exhibit new forms of the Echinodermata, chiefly the Asteriadæ. They are *Uraster carinatus*, *Tropidaster pectinatus*, *Luidia Murchisoni*, *Plumaster ophiuroides*, *Astropecten Hastingsiæ*, *Ophioderma Milleri*, *O. Gaveyi*, *O. carinatum*, *Ophiolepis Murrayi*, *O. columba*, and *Pentacrinus interbrachiatus*. These are chiefly northern species characterizing the Middle Lias of Yorkshire at Staithes, Boulby, Robin Hood's Bay (N. Cheek), Huntcliffe, &c.

The Lias in Gloucestershire and Worcestershire, as well as in Yorkshire, characterized by *Ægoceras Henleyi* contains nearly the same species as those just mentioned, *Rhabdocidaris Moraldina*, *Hemipedina Jardini*, *Ophioderma Brodiei*, and *Pentacrinus punctifer* being newly added. None of the German beds have yielded so large an Asteroidal or Crinoidal fauna as our own Middle and Lower Lias; but little can be said for the abundance of the Echinoidea all through the Lias.

The Asteroidea and Crinoidea in the widely-extended zone of *Amaltheus margaritatus*, which is to be traced from the Cleveland area in Yorkshire to the coast near Lyme Regis, are nearly the same species as in the preceding, *Pentacrinus gracilis*, however, being hitherto unobserved. The Scotch beds on this horizon do not appear to possess remains of either the Echinoidea or the Asteroidea. Although the deposits at Skye and Raasay are largely developed, the Yorkshire sections have hitherto yielded the richest harvest in this group: *Aspidura loricata*, *Astropecten Hastingsiæ*, *Ophioderma Milleri*, *Uraster carinatus*, *Ophiura Murrayi*, &c. all occur in the fine section at Staithes.

Upper Lias.—From Somersetshire to Yorkshire the Upper Lias carries with it successively or intermittently the series of clays and pseudo-limestones containing the defined horizons of *Stephanoceras annulatum*, *Harpoceras serpentinum*, and *H. bifrons*; and in these beds, mostly in the middle of England, occur *Acrosalenia crinifera*, *Cidaris ilminsterensis*, *C. Moorei*, *Diplocidaris Desori*, *Hemipedina Etheridgei*, *Palæocoma carinata*, 6 species of *Pentacrinus*, *Pseudodiadema Moorei*, and *P. wickense*. Not a single species of Echinodermata that I have named, nor any of the 53 species known to occur in the whole of the Lias, pass the upward limits of the formation, or are common to the Oolitic beds above.

Annelida.—Forty-five species have been described from the entire Jurassic series, from the Lias to the Portland. *Serpula*, *Vermilia*, and *Ditrypa* are the only three genera known in the Jurassic rocks, if we omit *Vermetus*. Fourteen species occur in the three divisions of the Lias, and illustrate the three genera named:—*Serpula*, with 8 species in the Lower and 3 in the Middle Lias; *Ditrypa*, with 2 species in the Middle Lias; and *Vermilia*, with 2 species in the Upper. *Serpula lituiformis*, *S. socialis*, and *Vermilia sulcata* are all that pass to the Inferior Oolite or any higher beds. We should have expected, from so large a specific fauna in the Lias (14 species belonging to only 3 genera), that more species would have passed to higher horizons, the division Tubicola (to which all belong) including moderately deep-sea forms, scarcely subjected to the same vicissitudes as certain genera of Mollusca, littoral in their habits.

The 45 species of Annelida are distributed very unequally through the Jurassic series: 11 species occur in the Inferior Oolite, 3 in the Fuller's Earth, 7 in the Great Oolite, 1 in the Forest-marble, 5 in the Cornbrash, 1 in the Kellaways Rock, 2 in the Oxford Clay, 7 in the Coral Rag, 3 in the Kimmeridge Clay, and 4 in the Portland

Oolite, which, with the 14 in the Lias, gives nearly 60 appearances. Few species have a long range; three, however, may be named—*Serpula intestinalis*, from the Great Oolite to the Coral Rag; *Serpula tricarinata*, from the Fuller's Earth, intermittently, to the Coral Rag; and *Serpula lacerata*, Great Oolite and Coral Rag. The remainder are scattered according to their habitat and the shells &c. to which they are attached.

Crustacea.—Of the 24 genera and 64 species that are known in the Jurassic rocks, 14 genera and 42 species occur in the Lias—12 genera in the Lower Lias, 1 in the Middle, and 6 in the Upper; and, respectively, 33, 1, and 12 species. No Liassic species passes the limits of the Upper Lias: 13 of the 33 Lower-Lias species belong to the Ostracoda (*Bairdia* 4 species, *Cytherella* 1, *Cythere* 7, *Polycope* 1); these are of little value in classification. No species is common to both the Lower and Middle Lias; and 3 species (*Eryon antiquus, Glyphea Heerii*, and *Palinurus longipes*) are Lower and Upper Lias only, not having as yet been found in the intermediate or Middle Lias. The chief genera are *Eryon*, *Eryma*, and *Glyphea*. *Eryon* is entirely confined to the Lias (5 species in the Lower and 3 in the Upper). *Eryma* also, with one exception (*E. Babeaui*), is confined to the Lias, 3 species being in the Upper division. *Glyphea*, with 11 species, is represented by 5 Lower-Lias, 1 Upper-Lias, and 1 Great-Oolite species, 3 Cornbrash, 2 in the Kellaways Rock, 2 in the Oxford Clay, 2 in the Coral Rag, and 2 in the Kimmeridge Clay, making 18 appearances through the same species occurring in different horizons. Four genera (*Æger*, *Scapheus*, *Pseudoglyphea*, and *Hefriga*) have only 1 species each. The 3 former are, however, Lower Lias, and the last named is an Upper-Lias genus. It may be said that not a single species occurs in the Middle Lias, for only an Ostracod (*Cytherella crepidula*) seems to enjoy the privilege of being alone in that division. Nine of the 12 species that occur in the Upper Lias are peculiar to it; owing to their value as illustrating the Upper Lias and not ranging to higher horizons, I name them:—*Eryon Hartmanni, E. Moorei, Eryma elegans, E. fusiformis, E. Greppini, Hefriga Frischmannii, Palinurina pygmæa, Penæus latipes*, and *P. Sharpei*.

Bryozoa.—Only 3 genera and 6 species are known in this division of the Jurassic rocks, although 19 genera and 51 species range through the entire series. The Great Oolite yields by far the greatest number of species (31); the Inferior Oolite, next in value, has yielded 7 genera and 17 species. The Lower-Lias genera are *Berenicea*, *Neuropora*, and *Spiropora*, with 4 species. *Spiropora liassica* is a Middle-Lias form, and the only species occurring in that division. *Berenicea Archiaci* is the only species that has yet appeared in the Upper Lias. No form passes to the Inferior Oolite, although 17 species are recorded from that horizon. The single form in the Fuller's Earth is *Terebellaria ramosissima*. The higher beds will be described in their turn.

Brachiopoda.—*Lower Lias*. The Liassic Brachiopoda number 16 genera, with 124 species, 10 genera and 36 species of which occur in

the Lower Lias; of these, 16 species pass to the Middle Lias, and 7 occur in *all three* divisions. These last are *Discina reflexa*, *Rhynchonella furcillata*, *R. variabilis*, *Spiriferina rostrata*, *Thecidium Moorei*, *T. rusticum*, and *T. triangulare*. *Rhynchonella* is represented by 64 species in the Jurassic rocks, with 91 appearances. Another rich genus is *Terebratula*, in which 67 species occur; and *Waldheimia* has 44. To show their distribution through Jurassic time, I append the following short Table (XX.). The remaining 13 genera are very restricted in range, which gives them their chief significance. This will be apparent when I construct a general Table of the distribution of the Brachiopoda at the close of the Jurassic period.

TABLE XX.

	Species.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland Oolite.	Total appearances.
Terebratula	67	4	10	3	31	5	7	4	5	3	2	7	2	2	85
Waldheimia	44	3	13	3	13	4	4	3	8	3	3	6	...	1	64
Rhynchonella ...	64	9	19	10	23	4	5	3	5	3	2	3	4	1	91
		16	42	16	67	13	16	10	18	9	7	16	6	4	240

Middle Lias.—No less than 14 genera and 74 species occur in the Middle Lias. The three chief genera in the above Table yield 42 species. Only 4 species of *Rhynchonella* pass to the Upper Lias, viz. *R. furcillata*, *R. pygmæa*, *R. variabilis*, and *R. cynocephala*; none to the Inferior Oolite or higher beds. In *Terebratula* only 1 species (*T. globulina*) is common to the Middle and Upper Lias, and none out of the known 12 ranges higher. *Waldheimia*, according to the last reconstruction of the genus, and the removal to it from the genus *Terebratula* of certain forms found to differ essentially from the latter in their internal structure, now numbers 44 species, 13 of which occur in the Lower Lias, 13 in the Inferior Oolite, and 8 in the Cornbrash; the remaining species are irregularly distributed through the other ten horizons. *Terebratula* is the genus most largely represented in the Jurassic rocks. In the Inferior Oolite 31 species are known, and in the Middle Lias 10. The remaining 11 genera average only 4 species in each. In the Lower Lias 4 species are known, in the Middle Lias 10, and in the Upper Lias only 3.

LAMELLIBRANCHIATA.—Few perhaps would believe, unless they paid close attention to the palæontology of the Jurassic rocks, that no less than 1368 species of Lamellibranchiate Mollusca occur in the 13 divisions. The Lias alone has yielded 65 genera and 457

species, 171 Monomyarian and 286 Dimyarian forms. They are thus distributed:—

Monomyaria.—18 genera and 114 species occur in the Lower Lias.
16 „ 60 „ „ Middle Lias.
13 „ 32 „ „ Upper Lias.

Only 5 genera and 8 species pass up to the Oolitic rocks, and thus unite the two formations, clearly showing that considerable change must have taken place in the physical conditions of the sea on the introduction of the more calcareous deposits of the Oolitic rocks. 10 of the 18 genera and 23 of the 114 species in the Lower Lias pass to the Middle Lias; but only 2 genera and 2 species are common to the Lower, Middle, and Upper divisions, viz. *Lima punctata* and *Pecten textorius*; and *Lima punctata* ranges to the Inferior Oolite. This clearly shows the restricted range of the species of the Lower and Middle Lias. Of the 16 genera and 60 species that occur in the Middle Lias, 6 genera and 8 species pass to the Upper Lias, and 5 genera and 8 species to the Inferior Oolite. In the Upper Lias 22 of the 32 species are confined to it. The number of Monomyarian species that pass from the Lias to the Oolitic rocks is 13, the connexion occurring through *Lima bellula*, *Perna rugosa*, *Avicula inæquivalvis*, *Hinnites abjectus*, *H. velatus*, *Lima electra*, *L. punctata*, *Pecten demissus*, *P. articulatus*, *P. comatus*, *Pinna fissa*, *P. Hartmanni*, and *Gervillia Hartmanni*. So restricted are the species that only 6 of the above 13 range higher into the Oolitic rocks than the Inferior Oolite, viz. *Hinnites abjectus*, *H. velatus*, *Lima bellula*, *Pecten demissus*, *P. articulatus*, and *Perna rugosa*.

In Yorkshire Messrs. Tate and Blake have exhaustively studied the whole Lias series, placing in the several Ammonite-zones their associated Molluscan contents. The following Table exhibits, as near as can be, the result of their Yorkshire labours in the single group Monomyaria:—

	The zone of						
LOWER LIAS.	*Ægoceras planorbis*	contains	4 genera	and	6	species.	
	„ *angulatum*......	„	9	„	20	„	
	Arietites Bucklandi	„	12	„	23	„	43/77
	Amaltheus oxynotus	„	7	„	11	„	
	Ægoceras Jamesoni	„	11	„	17	„	
MIDDLE LIAS.	*Ægoceras capricornus* ...	„	9	„	15	„	
	Amaltheus margaritatus.	„	10	„	17	„	30/54
	„ *spinatus*	„	11	„	22	„	
UPPER LIAS.	*Stephanoceras annulatum*	„	5	„	7	„	
	Harpoceras serpentinum .	„	4	„	5	„	17/24
	Stephanoceras commune .	„	4	„	6	„	
	Lytoceras jurense	„	4	„	6	„	
			90	„	155	„	

These twelve zones are clearly defined in Yorkshire, and may be studied along the coast, from the Peak to Redcar, in many of the deep valleys, and on the tableland of Lofthouse, Easington, and the

Cleveland area. They are distributed through about 1300 feet of strata*.

The Monomyarian fauna of the Lias of other typical localities varies much in number of species. That of the zone of *Ægoceras planorbis,* in Britain, seldom exceeds 6 or 8 species; on the continent, at Halberstadt, Württemberg, in Swabia, the Côte d'Or, &c., it is extensively developed and rich in species.

The zone of *Arietites Bucklandi* at Saltford, near Bristol, at Lyme Regis, near Watchett, in the Harbury beds, at Penarth Head, and in Lincolnshire gives much the same general result in collecting as that of Yorkshire, namely, about 10 genera and from 18 to 20 species. The French deposits in the Côte d'Or also yield almost the same species and percentage.

The beds with *Ægoceras Jamesoni,* near Cheltenham, have yielded 6 genera and 13 species.

Fenny Compton, in Warwickshire, has a very large fauna, 12 genera and 28 species of the Monomyaria; but this fine section has yielded no less than 206 species in all groups. This is due to the careful collecting and critical knowledge of Mr. Beesley, of Banbury. The same zone at Radstock yields 15 species; and its extended range to Scotland (Pabba, Skye, and the Hebrides) 13 species, and in almost every instance the same.

The *Ægoceras-Henleyi* beds at Mickleton, Lyme Regis, Charmouth, Cheltenham, &c. furnish about the same number. The *Amaltheus-margaritatus* beds in Gloucestershire, Dorsetshire, and Somersetshire, and in the islands of Raasay and Skye, are the same, species for species. The succeeding *Amaltheus-spinatus* beds in Gloucestershire, Dorsetshire, and Skye give the same result. This zone, in its several localities, varies but little; the same genera and species occur everywhere.

The well-known beds containing *Harpoceras bifrons, Stephanoceras commune,* and *S. crassum,* which range from Whitby to Somersetshire, under many lithological aspects, have yielded to Mr. Beesley, from the eastern portion of the Banbury and Cheltenham railway at Bloxham, in Oxfordshire, a rich series of organic remains; amongst them the Mollusca are very numerous. No less than 22 species of Cephalopoda occur (12 Ammonites, 8 Belemnites, and 2 Nautili). Of Gasteropoda 10 genera and 12 species; Lamellibranchiata 18 genera and 25 species; Brachiopoda 4 genera and 7 species; Annelida 1 genus and 6 species; Echinodermata 4 genera and 4 species; Crustacea 2 species; and Rhizopoda (Foraminifera) 8 genera and 24 species; in all 50 genera and 102 species. Amongst the Ammonites in this section occur *Lytoceras cornucopiæ* and *Phylloceras heterophyllum,* the latter species being by no means common in the south and west of England.

* *Vide* Tate & Blake, 'Yorkshire Lias,' pp. 193–197, and *passim.*

TABLE XXI.—*Showing the value of 12 chief Genera of Monomyarian Mollusca in the three Divisions of the Lias with relation to the same Group in the whole of the Jurassic rocks.*

Chief Monomyarian genera in the Lias.	Number of Species in Jurassic rocks.	Number in Lias.	Species in the Lower, Middle, & Upper Lias.			
			Lower Lias.	Middle Lias.	Upper Lias.	Appearances.
Avicula	42	18	14	3	4	21
Gervillia	33	11	5	3	3	11
Gryphæa	16	7	4	4	2	10
Hinnites	14	7	3	2	3	8
Inoceramus	12	6	1	2	3	6
Lima (Radula)	77	29	23	10	3	36
Ostrea	59	18	14	3	2	19
Pecten	90	32	21	16	4	41
Perna	17	4	2	...	2	4
Pinna	15	7	5	4	1	10
Placunopsis	9	1	...	...	1	1
Plicatula	19	12	9	4	1	14
	403	152	101	51	29	181

Carpenteria, *Placunopsis*, *Posidonia*, *Posidonomya*, *Pteroperna*, and *Spondylus* yield only 1 species each, and the characteristic genus *Crenatula* 2 species.

Dimyaria.—This great and important group of the Mollusca occupies a prominent position in the history of the Lias, which exceeds the Carboniferous in number of species, the numerical value of the genera being the same. 245 species are known in the Carboniferous rocks; and the Lias in all three divisions has, up to the present time, yielded 45 genera and 286 species,

the Lower Lias	yielding	36	genera	and	138	species,
the Middle	,,	34	,,	,,	108	,,
the Upper	,,	25	,,	,,	69	,,

with comparatively few passing to the higher members of the Jurassic group.

11 genera	and	12	species	pass to the	Inferior Oolite,
5 ,,	,,	5	,,	,,	Fuller's Earth,
6 ,,	,,	6	,,	,,	Great Oolite,
1 genus	,,	1	,,	,,	Forest Marble,
2 genera	,,	2	,,	,,	Cornbrash.

No Lias form appears above the Cornbrash.

The preponderating genera (16), or those having most specific representatives in the Lias, are given in the following Table (XXII.):—

TABLE XXII.

Chief genera.	Number of Species in Genera.	Lower Lias.	Middle Lias.	Upper Lias.	Appearances.
Arca	11	6	2	3	11
Astarte	19	5	6	9	20
Cardinia	27	22	11	...	33
Cardium	8	4	2	2	8
Cucullæa	11	6	2	3	11
Cypricardia	13	6	4	3	13
Goniomya	6	3	3	3	9
Gresslya	11	3	5	3	11
Leda	21	9	10	3	22
Modiola.......................	15	8	6	3	17
Myacites	6	2	2	4	8
Mytilus	9	4	4	1	9
Nucula	9	2	4	4	10
Pholadomya	16	8	6	4	18
Pleuromya	16	5	8	5	18
Tancredia	11	5	3	3	11
	209	98	78	53	229

The value of the same 16 genera I now give (Table XXIII.) for the whole of the Jurassic rocks to show increase or decrease in time, from the Lias upwards; this is, of course, only so far as we know; but it helps us to understand the distribution, both in space and time, when the faunas of sections are under consideration:—

TABLE XXIII.

Species in the Lias.	Chief genera.	Number known in all the Jurassic rocks.	LOWER.				MIDDLE.				UPPER.		Appearances above the Lias.
			Inferior Oolite.	Fuller's earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian Rocks.	Kimmeridge Clay.	Portland.	
11	Arca	45	12	...	10	1	1	...	2	5	3	...	34
19	Astarte	77	24	1	21	6	7	4	4	8	7	2	84
27	Cardinia	29	1	...	1	...	...	...	...	...	...	...	2
8	Cardium	35	6	1	10	1	7	6	3	3	2	4	43
11	Cucullæa	37	16	4	4	...	2	4	4	4	...	1	39
13	Cypricardia	26	5	2	4	2	2	...	...	2	1	...	18
6	Goniomya	15	3	2	5	...	2	1	...	3	4	...	20
11	Gresslya	19	3	2	3	...	1	1	...	1	...	...	11
21	Leda	31	2	...	2	1	5	...	1	...	1	1	13
15	Modiola...........	44	9	6	14	2	7	5	1	7	3	2	56
6	Myacites	33	11	5	7	1	8	6	1	4	1	3	47
9	Mytilus	25	9	...	2	...	2	...	1	1	1	3	19
9	Nucula	19	3	1	2	...	1	1	2	...	1	2	13
16	Pholadomya	49	11	8	12	1	10	7	4	6	3	3	65
16	Pleuromya	23	3	...	...	...	...	...	1	1	1	1	7
11	Tancredia	26	10	...	9	1	...	1	1	...	...	...	22
209		533	128	32	106	16	55	36	25	45	28	22	493

Besides these 16 genera quoted from the Lias, there are others of much importance, zoologically considered, having first appeared with these in time. Amongst them must be named *Anatina*, *Arcomya*, *Cardita*, *Ceromya*, *Hippopodium*, *Homomya*, *Macrodon*, *Myoconcha*, *Opis*, *Protocardium*, *Trigonia*, *Unicardium*, &c. Most of these genera play an important part in the history of the Lower and Upper Secondary rocks, especially the Jurassic, which will be alluded to under their respective horizons. These 12 genera include 195 species, all of which occur in the Jurassic group, including the Lias, which forms so important an integer at the base: 51 of the 195 are Lias species generally, 22 are Lower-Lias proper, 24 Middle-Lias, and only 9 occur in the Upper Lias. *Cyprina*, *Gastrochæna*, *Isocardia*, *Lithodomus*, *Myophoria*, *Quenstedtia*, *Sowerbya*, *Solen*, and *Thracia* are only represented in the Lias by 1 species each. Closer search will doubtless add to this scanty specific fauna. The accompanying Table (XXIV.) illustrates the distribution of the above 12 genera through the Lias.

TABLE XXIV.—*Additional Genera to the 16 before tabulated occurring in the Lias.*

Genera.	Number of Species in Jurassic.	Number in Lias.	Lower Lias.	Middle Lias.	Upper Lias.	Appearances in the Lias.
Anatina	11	3	1	2	...	3
Arcomya	5	5	2	4	...	6
Cardita	6	5	3	2	...	5
Ceromya	18	5	1	3	1	5
Hippopodium	4	4	2	2	...	4
Homomya	6	2	1	1	...	2
Macrodon	7	5	3	2	...	5
Myoconcha	14	5	4	1	...	5
Opis	20	4	1	2	1	4
Protocardium	4	3	2	1	...	3
Trigonia	88	5	...	1	4	5
Unicardium	12	5	2	3	3	8
	195	51	22	24	9	55

Following on the analysis made of the Monomyarian group from the Lias of Yorkshire, I now do the same for the Dimyaria from the same area, which important district cannot be overlooked, first on account of the high development and stratigraphical value of the whole of the Lias formation there, and, secondly, owing to the exhaustive nature of the researches of Messrs. Tate and Blake, which have caused the Lias of Yorkshire to be regarded as a type to which we must now refer the rest of Britain. Accepting then, as I do, the value of the Ammonite-zones as a means of registering the fauna of

a given set of beds thus characterized, I give the value of the Dimyarian fauna of the Yorkshire Lias in the following 12 zones adopted by the above authors:—

	The zone of					
Lower Lias.	*Ægoceras planorbis*	contains	7	genera and	8	species.
	„ *angulatum*......	„	17	„	31	„
	Arietites Bucklandi	„	19	„	33	„
	Amaltheus oxynotus	„	12	„	14	„
	Ægoceras Jamesoni	„	20	„	28	„
Middle Lias.	„ *capricornus* ...	„	11	„	17	„
	Amaltheus margaritatus.,	„	17	„	30	„
	„ *spinatus*	„	24	„	40	„
Upper Lias.	*Stephanoceras annulatum*	„	12	„	13	„
	Harpoceras serpentinum..	„	5	„	5	„
	Stephanoceras commune ..	„	5	„	6	„
	Lytoceras jurense	„	5	„	5	„
			154	„	230	„

The affinity between the Liassic Dimyarian Lamellibranchs and those of the succeeding Inferior Oolite is manifested only through 11 genera and 12 species. This emphatically shows a great change in the physical condition of the sea-bed, when the whole of the Dimyarian Bivalves, numbering 286 species, less the 12 (274), ceased to exist or otherwise migrated. The 11 genera and 12 species are *Astarte modiolaris*, *Cypricardia acutangula*, *Goniomya angulifera*, *Homomya crassiuscula*, *Leda lachryma*, *Modiola Sowerbyana*, *Myacites tenuistriatus*, *Myoconcha crassa*, *Mytilus lunularis*, *Pholadomya fidicula*, *Trigonia formosa*, and *T. spinulosa*. The determination of these connecting species as bearing upon distribution under physical changes, enables us to state confidently the lines of demarcation between large divisions of the stratified rocks where a physical unconformity does not exist; yet causes existed at the time of deposition to extensively modify the then existing fauna. Five genera and 5 species range from the Lias to the Fuller's Earth; 6 genera and 6 species to the Great Oolite; and only 2 species to the Cornbrash, viz. *Homomya crassiuscula* and *Leda lachryma*, both moderately deep-sea forms. Comparing then the figures which numerically represent the Dimyarian fauna of the Lias with those of the immediately succeeding and conformable Oolitic rocks, the result is remarkable. It will stand thus:—

In the Lias	45	genera and	286	species occur;				
	36	„	„	138	„	are in the	Lower	Lias,
	34	„	„	108	„	„	Middle	„
	25	„	„	69	„	„	Upper	„

of which only 11 genera and 12 species pass to the Inferior Oolite, whose Dimyarian fauna numbers 47 genera and 236 species. Thus these two extensive formations, whose united Dimyarian fauna alone equals 62 genera and 522 species, are linked together by only 12 species belonging to 11 genera, and only 2 species from the whole of the Lias pass to the Cornbrash. This small but representative series of species which passed the confines of the Upper Lias and

connected (with other groups) the Lias and the Lower Oolite, requires critical examination; they are all abnormal either in size or habit, dwarfed or semideformed.

Very few species occur in the lowest zones of the Lower Lias. Those beds, characterized by the presence of *Ægoceras planorbis*, possess only 3 or 4 species, *Protocardium Phillipsianum*, *Pleuromya crowcombeia*, *Unicardium cardioides*, and a *Cardinia* allied to *C. crassiuscula*. All these pass to the Angulatum-beds above, in one or other of the areas, where exposed; they are also common continental species at the same horizon. Mr. E. B. Tawney, in his paper "On the Western Limits of the Rhætic beds in South Wales"*, and Professor Tate, in his memoirs, "On the Fossiliferous Development of the Zone of *Ammonites angulatus* in Great Britain"†, and "On the Lower Lias of the North-east of Ireland," discuss this distribution. Mr. Tawney, in 1866, was the first to notice the extension of the Rhætic and Infra-Lias beds in their most westerly range or extension; for the first time, too, the white Sutton-stone series received from him careful attention. We were then made acquainted with the series of beds at the Southerndown cliff, at the base of which, immediately above the Chert band, Mr. Tawney obtained *Ostrea multicostata* and *Lima tuberculata*, the former a Muschelkalk species, which, with the Astrocœnian corals, also mostly of that age, gave rise to the hope that we may have in that area some direct representative of the missing member of the Trias in Britain. Two Ammonites were detected by Mr. Tawney in the Sutton-stone series. From these white beds he obtained 33 species; from the succeeding Southerndown beds 12; and from the *Avicula-contorta* beds 25 species. The *Avicula-contorta* series, noticed so far west in England for the first time, numbered 25 species; 7 genera of Monomyaria, and 4 genera of Dimyarian Mollusca, with 21 species, occur in the Sutton Stone. Professor Tate in 1863 described the Rhætic and Liassic strata near Belfast; from the latter he obtained 55 species, 13 amongst them being Monomyarian bivalves and 16 Dimyarian.

In 1867, in his paper published in the Journal of our Society upon the Lower Lias of the N.E. of Ireland, Mr. Tate regarded the Lower Lias of Ireland as capable of being divided into 4 members or series, namely:—

1, the zone of *Ægoceras planorbis*; 2, the zone of *Ægoceras angulatum*; 3, the zone of *Arietites Bucklandi*; and 4, beds superior to those with *A. Bucklandi*, which he termed the *Belemnites-acutus* zone, the equivalent of the "Belemnitic beds" of the Lower Lias of France, Germany, and England (Lyme Regis), and the highest beds of the Lias known in Ireland. The singular "Portrush" beds Mr. Tate unhesitatingly referred to the zone of *Ægoceras planorbis*; only 5 species of Dimyaria occur therein, the remaining 8 being Monomyaria; only 5 species of the whole 18 are restricted to the zone. The succeeding beds belong to the zone of

* Quart. Journ. Geol. Soc. vol. xxii. (1866).
† Ib. vol. xxiii. (1867).

Ægoceras angulatum, whose fauna is Hettangian, being identical with that of the Grès infraliasique de Hettange, and the Côte-d'Or beds containing *Ammonites Moreanus* inferior to those with *Ammonites Bucklandi* and *Lima gigantea*. The Bucklandi-beds with the persistent *Ostrea arcuata* (*Gryphæa incurva*) exceed all others; and the latter species marks with unerring certainty the above horizon, readily distinguishing the Bucklandi- from the Angulatus-series, which is equally crowded with *Ostrea irregularis*. Prof. Tate enumerates no less than 38 species from his zone of *Belemnites acutus* at Ballintoy, including 12 species of Dimyaria and 7 Monomyaria, with 9 Ammonites and 2 species of Belemnites.

In the same year Mr. Tate critically noticed and discussed the "Fossiliferous Development of the Zone of *Ammonites angulatus* in Great Britain," giving a copious list of the contents of the zone from five localities; 15 genera and 25 species of Dimyaria are given, chiefly from Ireland and Marton. The Monomyaria number 8 genera and 22 species. The series recorded by Mr. Tate from the Angulatus-zone includes 100 species—78 from the Irish beds, 46 from Marton, 12 from Down-Hatherly, 16 from Brocastle, and 4 from Sutton. 30 species are common to the Irish and Marton beds. In 1870 Mr. Tate again published an important paper upon the "Palæontology of the Junction-beds of the Lower and Middle Lias in Gloucestershire"*. He there records 50 species from the zones of *Amaltheus oxynotus* and *Arietites raricostatus*, and from the succeeding *Ægoceras-Jamesoni* beds no less than 116 species; 60 of these 116 pass to higher zones, and 14 species are common to the Lower and Middle Lias of that area. The Dimyaria number 16 genera and 27 species. Mr. Tate proposed upon faunal grounds to draw the line separating the Lower and Middle Lias between the zones of *Arietites obtusus* and *Amaltheus oxynotus*, thus giving a total of 164 species for the united zone, 6 passing to the Middle Lias.

The rich beds of the Jamesoni-zone at Fenny Compton, rendered conspicuous by the fine collection made from them by Mr. T. Beesley, F.C.S., of Banbury, have yielded a large Dimyarian fauna: no less than 19 genera and 35 species are in Mr. Beesley's collection from this one horizon and locality alone.

Few bivalve species occur in the zones of *Ægoceras Henleyi* and *Amaltheus ibex*. The only good description of the latter zone and its contents is due to the researches of Mr. E. B. Tawney, who has most carefully and critically examined the species in this zone near Radstock, in Somersetshire †. Here the Ibex-beds are associated with the Jamesoni-series, and seven or eight species of Ammonites, including *Ægoceras brevispina*, *Æ. Jamesoni*, and *Amaltheus ibex*, seem to be characteristic here. The Dimyarian fauna of the zone of *Amaltheus margaritatus* in Gloucestershire and Dorsetshire, as contrasted with that of Yorkshire, is not large. Again, in Rutland it can be divided into five sections, from the yellowish-brown sandy

* Quart. Journ. Geol. Soc. vol. xxvi. p. 394 (1870).

† "Notes on the Lias in the Neighbourhood of Radstock," Proc. Bristol Naturalists' Soc. vol. i. p. 178 &c. (1875).

strata up to the Limestone rock, or "Rock-bed." In Rutlandshire, as in Dorsetshire, *Stephanoceras commune* and *S. annulatum* are occasionally associated with the Marlstone, or Middle-Lias species, *Amaltheus spinatus*; yet they cannot be said to occur normally together. *Amaltheus spinatus* occupies the summit of the Middle Lias, and is immediately succeeded by *Stephanoceras commune* and *S. annulatum*. This division of the Lias constitutes a striking physical feature all through England, especially in the Midland counties; and its fossil contents are equally marked. The Middle Lias of Rutlandshire has been described by Professor Judd *; and every species known therein has been carefully noted by him. He names 5 species of Ammonites, 4 of Belemnites, 7 genera and 12 species of the group Dimyaria, and 11 genera and 13 species of Monomyaria, or 27 genera and 41 species, besides the characteristic species of Brachiopoda, to be obtained from the Marlstone of Rutlandshire. The Middle Lias of Gloucestershire, Dorsetshire, Somersetshire, Northamptonshire, and Lincolnshire yields the same forms, the fauna being more or less specifically abundant.

The important *upper division* of the Middle Lias, or the zone of *Amaltheus spinatus*, must be seen, to be understood, in all areas. In Yorkshire, as before stated, it is finely developed, physically and palæontologically. Hawsker Cliffs, Staithes, Boulby, and the Cleveland area all yield an abundant Lamellibranchiate fauna. Between 40 and 50 species of Dimyaria, belonging to 25 genera, enrich the Spinatus-beds. Everywhere on the continent it is the same; in Germany, France, and Belgium, all sections yield the same species. The succeeding Upper Lias, with *Harpoceras serpentinum* and *H. bifrons*, everywhere when fully developed yields proportionately about the same number of genera and species of Lamellibranchiata, and always the same Ammonites. The general condition of the Upper Lias and its fauna is delineated by Prof. Judd in the memoir on Rutland just quoted (*loc. cit.* pp. 79–89). I cannot pass over the important paper "On the Lias of Dorsetshire," by Mr. E. H. Day, published in 1863 †. Mr. Day has done more to elucidate the physical history and palæontology of the Middle and Upper Lias of Dorsetshire than any other investigator. It was at my suggestion, after I had prepared measured sections of the beds on the coast, that Mr. Day undertook to describe all above the Lower Lias. Sir H. de la Beche, thirty-four years previously (1829), had, in the 'Geol. Trans.' 2 ser. vol. ii., described generally the succession on lithological grounds. Much was known of the details of the Lower Lias through the extensive collections made "along shore" for saurians and fish ‡. I can do no more than refer to Mr. Day's paper for his physical facts, and give his results as to the fossil contents of the zones or particular beds. The Middle Lias of Black Ven,

* Mem. Geol. Surv., "Geol. of Rutland," &c. pp. 64–78, J. W. Judd, F.G.S. 1875.

† Quart. Journ. Geol. vol. xix. p. 278.

‡ The great series of fossil fish in the possession of Lord Enniskillen and the late Sir Philip Egerton came from the Lower Lias, which ranges from Pinhay Bay to the foot of Black Ven, the Middle Lias yielding few forms.

Stonebarrow Hill, and Westhay Cliff, the grand exhibition at Golden Cap, and the Middle and Upper Lias of Down Cliffs, are all delineated by Mr. Day in true dip succession. He enumerates 13 genera and 15 species of Monomyaria, and 30 genera and 35 species of Dimyaria, from the middle division of the Lias, along the Dorsetshire coast. From the so-called "Belemnite-beds," persistent in all the above-named cliffs, Mr. Day obtained evidence of the occurrence of 38 species—amongst them 9 species of Ammonites, the dominant species being *Ægoceras Henleyi*, *Æ. Bechei*, *Phylloceras Loscombii*, and *Lytoceras fimbriatum*; 5 species of Belemnites, and the remarkable *Xiphoteuthis elongata*, noticed by De la Beche thirty-six years before; 2 species of Nautili, and 2 Ichthyosauri, *I. communis* and *I. tenuirostris*. The remaining 19 forms are chiefly Lamellibranchiata.

The locally so-called Green Ammonite beds containing *Am. laticostatus*, Sow., with *Phylloceras Loscombi*, *Am. heterogenus*, and *Ægoceras Davœi*, are a marked feature in all the sections. These beds have yielded 16 species, 9 of them Cephalopoda, 4 Gasteropoda, and 2 Saurians; only 1 Lamellibranch has occurred. Beds called the "Three Tiers" conspicuously mark a special horizon in the cliffs at Westhay and Golden Cap, surmounted by the "Shell-bed," so called from its rich assemblage of Conchifera, about 30 species occurring. Resting upon this thin yet prolific Shell-bed is the well-known "Starfish-bed," containing *Ophioderma Egertoni* and its var. *O. tenuibranchiata*: this bed forms a remarkable feature in the grand face of the cliffs at Golden Cap. The fauna of the succeeding Middle Lias sands is then given by Mr. Day (25 species). He then notices the single bed of Marlstone above the sands with *Amaltheus spinatus*, which contains no less than 94 species, 18 Brachiopoda, 9 species of Monomyaria, 23 Dimyaria, 25 Gasteropoda, 8 species of Ammonites, with Belemnites, Echinodermata, Annelida, &c. The dying-out of the Middle Lias here, and the commencement of the Upper Lias, result in the appearance of 5 well-known Upper-Lias Ammonites, *Stephanoceras crassum*, *Harpoceras serpentinum*, *Stephanoceras commune*, *S. Holandrei*, and *Harpoceras radians*. The same thing occurs in Rutlandshire, at Edmondthorpe and Wymondham, as stated by Professor Judd in his memoir, p. 71. Mr. Day, in his endeavour to account for this abnormal condition, says:—"Nor is this bed, so valuable in the abundance of its palæontological evidence, less suggestive of physical facts. This thin and interrupted bed, which I consider to be the representative of the Marlstone, the pebbles and small boulders imbedded therein, the perforations of the *Lithodomi*, the masses of shells here and there collected into hollows, as it were, of the underlying rock, the *Serpulæ* covering the shells and pebbles, and the very intermixture of Upper-Lias species, all point to a sea-bottom upon which for a long period, little or no deposit took place, the waterworn fragments which lie upon it, on the contrary, indicating that, during that period, previously formed strata were again destroyed. From what I have seen of the junction of the Middle with the Upper Lias, both here and at Glastonbury in Somerset-

shire, I have been led to believe that, immediately previous to the deposition of the Upper Lias, some disturbing cause for a time changed the direction of the currents which had brought here the mud and sand of the Lower and Middle divisions, and that, in place of continuing gently to lay down these deposits, the action of the water was for a time, and over certain districts, confined to the destruction of beds previously formed and consolidated" *.

Mr. Day and myself had ample opportunities of examining this bed, both high up in the cliff and from fallen blocks on the shore. I doubt not it is the precise equivalent of the Calvados Middle and Upper Lias, the figures of the fossils in which Deslongchamps and D'Orbigny have made classical. The topmost layer also contains from 18 to 20 species. Probably nothing in Britain equals this bed for the crowded condition and perfection of its fossils, also a character which to some extent applies to the whole series of the Middle Lias group below.

The literature of the Lias and Oolite has been enriched by the Revd J. E. Cross with a description of a previously almost unknown area. In his paper in our 'Quarterly Journal' for Nov. 1875 †, Mr. Cross described a considerable portion of North-west Lincolnshire, carrying on, indeed, the work done by Prof. Judd and Mr. Sharp in the southern part of the county. "It is," remarks Mr. Cross, "a corner of the land unknown to fame," but now "celebrated commercially by the recent discovery of a most extensive and valuable deposit of iron-ore." This iron-ore deposit occurs in the Lower Lias, in the zones of *Arietites Bucklandi* and *Arietites semicostatus*. Mr. Cross minutely describes the physical aspect of the beds, ranging from the Angulatus-series to the Marlstone, above the zone of *Ægoceras capricornus*, and carefully describes in the text of his paper the leading features of the successive stages, and their chief associated fossils. His paper describes a series of ascending strata from the Keuper to the Great Oolite inclusive, with most carefully prepared lists of fossils from each formation. I can here only notice the Lias. From the Lower Lias of the valley of the Trent, Fordingham railway-cutting, the Scunthorp ironstone, and the *Pecten*-bed and its clay, Mr. Cross has obtained 48 genera, and 110 species, viz.:—

	Genera.	Species.
Ammonites..........	1	19
Belemnites..........	1	4
Nautilus............	1	1
Gasteropoda	3	7
Dimyaria	26	37
Monomyaria	9	31
Brachiopoda	5	7
Echinodermata	1	3
Cœlenterata	1	1
	48	110

* Day, Quart. Journ. Geol. Soc. vol. xix. p. 294.

† "On the Geology of North-west Lincolnshire," by the Rev. J. E. Cross, M.A., F.G.S., Quart. Journ. Geol. Soc. vol. xxxi. pp. 115–130 (1875).

From the Middle Lias of the Santon railway-cutting Mr. Cross obtained 16 genera and 26 species. Taken in connexion with the Yorkshire Lias to the north of the Humber, and the greatly developed beds of Lower and Middle Lias to the south of Mr. Cross's area of investigation, few papers have added more to our knowledge of the Lower Lias. The value of the work done in the higher members of the Jurassic group I will notice under that head. Six new species were added to the Lias and Oolite by Mr. Cross, viz. *Tancredia ferrea*, Cross; *T. liassica*, Cross; *Hippopodium ferri*, Cross; *Cucullæa Rolandi*, Cross; *C. suttonensis*, Cross; and *Astarte divaricata*, Cross. The three first named are Lower Lias, the remaining three Inferior Oolite. I have since visited the localities and sections described by Mr. Cross, with my late colleagues Messrs. Strangways and Ussher, adding greatly to my knowledge of the Brigg area and these Lower-Lias iron-ore beds.

Prof. Judd, in his Rutland Memoir (*loc. cit.*), has, from personal observation, named 21 genera and 52 species from the Lower Lias, and from the Middle Lias 22 genera and 38 species; but the fauna of the Upper Lias is poor in all but Ammonites, and this is the case generally south of the Humber. 15 genera and 28 species occur; but of this number 13 species belong to the Ammonites.

Gasteropoda.—No less than 76 genera and 1015 species of this class occur in the Jurassic rocks in the British islands; and 51 genera and 388 species are now known in the Lias. They are distributed as follows:—

41	genera and 226	species	occur in the	Lower Lias,
27	„ 136		„	Middle Lias,
19	„ 55		„	Upper Lias;

but only 6 *genera and* 6 *species pass to the Inferior Oolite*, none to the Fuller's Earth, and only 1 genus and species (*Amberlya capitanea*) to the Great Oolite and Forest Marble. None range higher. These 6 genera and 6 species I will dispose of at once. They are *Actæonina pulla*, *Amberlya capitanea*, *Cerithium papillosum*, *Natica adducta*, *Onustus pyramidatus*, and *Pleurotomaria princeps*. Those genera most largely represented, and therefore probably of the highest stratigraphical value, are the following:—

Actæonina, yielding	8 sp.,	3 of which	occur in L. Lias,	3 in M.	and	2 in	U. Lias.
Cerithium,	49	30	„	10	„	10	„
Chemnitzia,	23	15	„	8	„	2	„
Discohelix,	9	6	„	2	„	1	„
Eulima,	10	3	„	8	„	—	„
Melania,	9	9	„	—	„	—	„
Patella,	10	8	„	2	„	—	„
Pleurotomaria,	39	24	„	20	„	2	„
Trochus,	41	19	„	20	„	5	„
Turbo,	49	20	„	23	„	9	„
Turritella,	12	8	„	2	„	2	„
	259	145		98		33	

The genera *Alaria*, *Amberlya*, *Cryptænia*, *Littorina*, *Natica*, *Nerinæa*, *Neritopsis*, *Orthostoma*, *Phasianella*, *Pitonellus*, *Solarium*,

Straparollus, and *Tornatella* average 5 species each. The extremely rare genera having only one or two representative species each are:—*Delphinula* (*D. nuda*, in the Upper Lias, and *D. reflexilabrum* in the Lower); *Eucyclus* (*E. alpinus*, and *E. elegans*, Lower Lias); *Exelissa* (*E. numismalis*, Middle Lias); *Hydrobia* (*E. solidula*, Lower Lias); *Monodonta* (*M. modesta*, Middle Lias); *Nerita* (*N. alternata*, Lower Lias); *Proserpina* (*P. Lyelli*, Lower, and *P. liasina*, Middle Lias); *Onustus*, with 3 species; *Pterochilus* (*P. primus*, Lower); *Pyrula* (*P. liasica*, Lower); *Tectaria* with 3 species, all Middle; *Trochotoma* with 3 species, and *Rimula* with 3 species, all Lower Lias. Only one of these 24 species (*Onustus pyramidatus*) ranges higher than the Upper Lias. This, added to the fact that only 5 other species of the largely represented class Gasteropoda, and 20 Lamellibranchiata, pass to higher beds, shows how restricted is the whole Molluscan fauna of the Lias, which now numbers 948 species; *i. e.* 26 out of 950 in round numbers pass upwards. The forms occurring in the Fuller's Earth, Great Oolite, and Cornbrash are included among the 12 in the Inferior Oolite, but range higher. Of the 226 species of Gasteropoda occurring in the Lower Lias, only 18 pass to the Middle, and none to the Upper Lias, leaving 208 species as the absolute Gasteropod fauna of the lower division. The occurrences in the Middle Lias are 136 (true contents 118); but only 1 species (*Turbo spinulosus*) is common to this and the Upper Lias, out of the 136 (or 118) species. This analysis shows the value and significance of the three divisions, and the importance, both stratigraphically and palæontologically, of the tripartite arrangement.

Geographically, or in space, the Gasteropoda are intermittently distributed through England, the greatest known development being in Yorkshire and Warwickshire. I know of no species occurring in the zone of *Ægoceras planorbis* in England. In Yorkshire Messrs. Tate and Blake have recorded 14 genera and 26 species from the Angulatus-beds of Redcar; and Mr. Tate from the same zone, in five localities, Ireland, Marton, Cheltenham, Brocastle, and Sutton, cites 21 genera and 39 species. M. Martin and M. Collenot, the former in his 'Pal. Strat. de l'infra-Lias du Dépt. de Côte d'or,' and the latter in his 'Description Géologique de l'Auxois,' catalogue no less than 46 species from the zone of *Ægoceras angulatum*. 28 species are recorded by Tate and Blake from the *Arietites-Bucklandi* beds of Yorkshire. The zone of *Amaltheus oxynotus*, standing between the rich Bucklandi- and Jamesoni-beds, contains few species—only 5 or 6 genera and as many species. Nowhere in Europe is this zone rich in organic remains; and this is equally the case with the beds with *Arietites raricostatus*. From the famous Fenny Compton section in Warwickshire, and from the zone of *Ægoceras Jamesoni*, Mr. Beesley has obtained 30 species of Gasteropoda, representing 12 genera*. Mr. Tawney and Mr. Tate also record 18 species from the same zone at Munger, near Radstock; and Mr. Tate, in his paper "On the Palæ-

* Mr. Beesley has collected 200 species from this horizon at Fenny Compton.

ontology of the Junction-beds of the Lower and Middle Lias in Gloucestershire," enumerates 12 genera and 23 species of Gasteropoda from the Jamesoni-beds, 20 species of Belemnites, and 14 Ammonites; indeed from this one zone alone he catalogues 115 species; and from the same beds at Radstock 12 genera and 26 species of Gasteropoda. Neither the spinatus- or margaritatus-zones at Ramsay and Portree, in the Isle of Skye, although rich in Conchifera, have yielded any Gasteropoda; but from the same horizon in Yorkshire 24 species have been collected. The higher zones of *Stephanoceras annulatum*, *Harpoceras serpentinum*, *H. bifrons*, and *Lytoceras jurense*, in the same county, yield about 30 species. The remaining Gasteropod fauna in the Upper Lias is scattered in few species over many localities, hardly to be expressed save through tabulation. From the Middle Lias of Dorsetshire, through the researches of Mr. Day, 40 species have been recorded, and these chiefly from the Golden-Cap and Down-Cliff sections. To carry the analysis to individual sections, cliff or otherwise, in the Liassic rocks, would entail endless detail; and the authors named have exhaustively worked out the faunas their respective papers illustrate.

CEPHALOPODA.—*Ammonitidæ*. The species of Ammonites in the Lias exceed in number the whole of the species in the other divisions of the Jurassic rocks. The total number of known Jurassic species, including the Lias, is 477. The number known in the three divisions of the Lias is 293.

173	occur in the	Lower Lias,
54	"	Middle Lias,
79	"	Upper Lias;

and *only* 3 *species* pass to the succeeding Inferior Oolite; but I even doubt two of these.

Very few species are common to all three divisions of the Lias, either in England or on the continent of Europe; indeed critical study demonstrates that few or none pass even from the Lower to the Middle, or from the Middle to the Upper Lias, *and not a single form ranges through all three divisions in Britain.* The only 6 species common to the Lower and Middle Lias are *Ægoceras defossum*, *Æ. gagateum*, *Amaltheus Guibalianus*, *A. lenticularis*, *Ægoceras planicosta* ?, *Am. Robinsoni.* The only 3 species common to the Middle and Upper Lias are *Am. calypso*, *Lytoceras cornucopiæ*, and *Lytoceras fimbriatum.* Thus only 9 species out of 293 bridge over the two divisions of Lower and Middle and Upper and Middle Lias. I have stated that only 3 species of Ammonites connect the Upper Lias and the Inferior Oolite. Out of so large a specific fauna in one genus, and that a pelagic one, this is a remarkable generalization, and is not only given on my own authority, but through the direct analysis I have made of the works of reliable palæontologists, German, French, and English. I stated above that the species in the Lias exceed in number all in the 10 succeeding horizons. The most careful research shows that

the occurrences in the 10 horizons number 208. They are thus distributed:—

	Species.
Inferior Oolite	42
Fullers' Earth	5
Great Oolite	7
Forest Marble	2
Cornbrash	3
Kellaways Rock	41
Oxford Clay	45
Coralline Oolite	21
Kimmeridge Clay	31
Portland Oolite	11
	208

The same restricted range of species that occurs in the Lias is equally marked between the Inferior Oolite and the immediately succeeding rocks. Only one species (*Am. fuscus*) passes to the Fullers' Earth, none to higher beds. In stratigraphical geology the Ammonitidæ are of the highest importance; and their value for the purposes of correlation over distant and extended areas is admitted by all competent observers.

The families Ægoceratidæ and Arcestidæ range through the 8 Ammonitiferous zonal divisions; and the genus *Ægoceras* contains about 30 species.

	Species.
The zone of Ægoceras planorbis yields	2
,, angulatum	5
,, Arietites Bucklandi (lower zone)	1
,, ,, (upper zone)	3
,, Amatheus oxynotus	2
,, Arietites raricostatus	1
,, Ægoceras Jamesoni	20
	34*

The genus *Arietites* is well distributed through the Lower Lias, and represented by 18 species.

	Species.
The zone of Arietites Bucklandi (lower zone) yields	5
,, ,, ,, (upper zone)	6
,, ,, Turneri	3
,, ,, obtusus	2
,, ,, raricostatus	2
	18

The family Arcestidæ, through the genus *Amaltheus*, charac-

* Martin Simpson describes upwards of 50 species from the Lower Lias of Yorkshire.

terizes only one zone, that of *Am. oxynotus*, in which there are 6 species.

The stratigraphical or zonal distribution of the Middle-Lias Ammonites, also through the 6 zones, is as follows:—

		Species.
The zone of	Ægoceras armatum	3
,,	,, Jamesoni	4
,,	Amaltheus ibex	5
,,	Ægoceras Henleyi	8
,,	Amaltheus margaritatus	4
,,	,, spinatus	2
		26

In the family Lytoceratidæ, the genus *Phylloceras* contains 2 species and *Lytoceras* 2 species in the Middle Lias.

The Upper Lias contains 36 species, *Lytoceras* 4, *Phylloceras* 2, *Harpoceras* 24, and *Stephanoceras* 6 species.

The zone of	*Harpoceras serpentinum*	7 species.
,,	,, *bifrons*	15 ,,
,,	*Lytoceras jurense*	13 ,,
,,	*Harpoceras opalinum*	4 ,,

For lists of some species in the above zones see Dr. Wright, (Monogr. Lias Ammonites, Pal. Soc. part ii. Lias Form. pp. 66, 113, and 163).

The zone of *Arietites raricostatus* has been recognized in the British Islands, Switzerland, France and Germany, Austria and Italy.
,, *Amaltheus oxynotus* in England, France *, Switzerland, Germany *, and Austria.
,, *Arietites obtusus* in England, Belgium, France, Switzerland, Germany, Austria, and Italy.
,, ,, *Turneri* in England, Belgium, France, Switzerland, Germany, and Italy.
,, ,, *Bucklandi* in the British islands, Belgium, France, Switzerland, Germany, Austria, and Italy.
,, *Ægocerus angulatum* in the same areas.
,, ,, *planorbis* in all but Italy.

Associated with these Lower-Lias Ammonites in their respective zones, in all the above regions, occurs nearly the same fauna as in the British isles. The Middle and Upper Lias type forms exhibit the same constancy in distribution, except that in France two more departments possess the Middle-Lias zones, represented by a rich fauna.

* France in four departments, and Germany in Hanover and Würtemberg.

The constant Middle-Lias zonal divisions are the six following:—

Amaltheus spinatus, represented in Britain, Belgium, France (6 departments), Switzerland, Germany, Austria, Italy.

„ *margaritatus*, Britain, Belgium, France (6 departments), Switzerland, Germany, Austria, Italy.

Ægoceras Henleyi, Britain, Belgium, France (6 departments), Switzerland, Germany, Austria, Italy.

Amaltheus ibex, Britain, Belgium, France (6 departments), Switzerland, Germany, Austria, Italy.

Ægoceras Jamesoni, Britain, Belgium, France (4 departments), Switzerland, Germany, Austria, Italy.

„ *armatum*, Britain, Belgium, France (2 departments), Switzerland, Germany, Austria, Italy.

The Upper-Lias Ammonites that *everywhere* characterize similar definite horizons are the four following:—

Harpoceras opalinum, England, Scotland, Belgium, France, Switzerland, Germany, Austria, Italy.

Lytoceras jurense, England, Scotland, Belgium, France, Switzerland, Germany, Austria, Italy.

Harpoceras bifrons, England, Scotland, Belgium, France, Switzerland, Germany, Austria, Italy.

„ *serpentinum*, England, Scotland, Belgium, France, Switzerland, Austria, Italy.

These 16 zones in the Lias, as they appear in time, hold a special fauna, and most of the species equally characterize the horizon in which they occur. The whole of the Secondary rocks, from the base of the Lias to the highest Chalk, have thus been subdivided and specialized by the Ammonitidæ—a classification holding good for Europe, India, and America, many species being the same both in the eastern and western hemispheres *.

The whole of the 293 species in the Lias fall under these sectional divisions. A careful study of the Table (XXVI.) devoted to the analysis of the Liassic species reveals the remarkable fact that, with the exception of the *Lamellibranchiata*, of which 25 are common, only 20 species out of 1827 passed to the Inferior Oolite, or in all only 33 genera and 45 species of all groups passed to the Inferior Oolite. They are Annelida $\frac{2}{3}$, Brachiopoda $\frac{5}{8}$, Monomyaria $\frac{8}{13}$, Dimyaria $\frac{11}{12}$, Gasteropoda $\frac{6}{6}$, and Ammonites $\frac{1}{3}$. No more complete palæontological change occurs throughout the British rocks in one great conformable group. The result of the analysis of every thing known in the Lias, and the community of all species with the rocks above is expressed in the following Table (XXV.), which shows the number of species that pass from the Lias to the higher divisions of the Jurassic rocks.

* Consult the works of Studer, Suess, Waagen, Von Hauer, Reynès, Quenstedt, Oppel, Dumortier, Hart, Barrois, &c., Wright, Judd, Tate and Blake, and many others.

TABLE XXV.

Lias.					Inferior Oolite.	Fullers' Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways rock.	Coralline Oolite.	Kimmeridge Clay.	Portland.
Genera.	Species.	Lower Lias.	Middle Lias.	Upper Lias.									
281	1830	$\frac{223}{1080}$	$\frac{137}{562}$	$\frac{113}{418}$	$\frac{33}{45}$	$\frac{7}{7}$	$\frac{11}{11}$	$\frac{2}{2}$	$\frac{4}{4}$	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{3}{3}$	$\frac{2}{2}$
					17 genera and 21 species are Bivalves.	5 genera and 5 species are Bivalves.	6 genera and 6 species are Bivalves.						
Whole Lias Fauna.		Genera and species in each division.			Bivalves.			The above are all Mollusca except $\frac{2}{3}$ Annelida in the Inferior Oolite.					

Three Ammonites only are known to pass the boundary line between the Upper Lias and the Inferior Oolite; they are *Harpoceras insigne*, *Harpoceras radians*, and *Harpoceras concavum.* They are Upper-Lias forms, and lived on through the physical change that took place, or the transition from the conditions of argillaceous and, in places, arenaceous deposition, to those under which calcareous deposits were formed, the latter of which prevailed, with the exception of the Fuller's-earth episode (a local one), up to the Oxfordian stage. The manifest change in the molluscan fauna from the Inferior Oolite to the Fuller's Earth clearly shows the influence due to sedimentary habitat. As a group of species, probably no other so completely died out at a special age as did that of the Ammonitidæ. 293 species have been recorded from the Liassic strata of Britain; 173 of these occurred in the Lower Lias, 54 in the Middle Lias, and 79 in the Upper, and only 2 or 3 of the Upper-Lias forms passed to the Inferior Oolite. Even between the Lower and Middle Lias 167 species had either migrated or died out; for only 6 species out of the 173 passed onwards and upwards into the Middle Lias, and, as already stated, *not a single species of Ammonite is common to all three divisions of the Lias in Britain.*

Nautili.—Ten species are known in the Lias; the occurrences are 6 in the Lower Lias, 4 in the Middle Lias, and 3 in the Upper. The typical species are *N. intermedius*, *N. latidorsatus*, *N. striatus*, *N. semistriatus*, and *N. truncatus.* No species passes to the Inferior Oolite, neither do we know of any species being common to all three of the divisions of the Lias. In so pelagic a form we should

scarcely expect to find that the species occupied a given area for a long period of time without modification; hence the 6 Lower-Lias species may have stocked the succeeding Middle and Upper deposits. But only one species, *N. striatus*, is both Lower and Middle Lias, and the only two species common to the Middle and Upper Lias are *N. inornatus* and *N. semistriatus*.

Teuthidæ.—This division of the Dibranchiata is but feebly represented in the Lias. *Geoteuthis bollensis* is essentially Lower Lias; *Beloteuthis Leckenbyi* and *B. subcostatus* are Upper only, and do not occur higher. 3 genera and 4 species are all that are known.

Belemnitidæ.—115 species are known to occur in the Jurassic rocks of Britain, 65 of which belong to the three Liassic divisions. 21 occur in the Lower Lias, 27 in the Middle Lias, and 34 in the Upper. *Not one of the species* passes to the Inferior Oolite, in any area in Britain, or Europe. 7 species are common to the Lower and Middle Lias; they are *Belemnites calcar*, *B. clavatus*, *B. longissimus*, *B. Milleri*, *B. nitidus*, *B. penicillatus*, and *B. virgatus*. Only one species, *B. Milleri*, appears to be present in all three divisions of the Lias.

The Lias of Yorkshire through the researches and labours of Hunton, Phillips, Simpson, Leckenby, Tate, and Blake have yielded a large number of species; and to no one more than Mr. Simpson are we indebted for collecting and describing the species occurring in the Lias of Yorkshire. Prof. Phillips's monograph in the Palæontographical Society's Memoirs is the only reliable British work we possess since the memoir by Miller in the Trans. of the Geol. Soc. vol. ii. 1829. Simpson's small but valuable work on the Lias of Yorkshire describes no less than 40 species. The close of the Lias brought with it a very great diminution of this group of the Dibranchiata; only 16 species are known in the Inferior Oolite, 3 in the Fuller's Earth, 3 in the Great Oolite, none either in the Forest Marble or Cornbrash, 3 species in the Kellaways Rock, 13 species in the Oxford Clay, declining to 4 species in the Corallian beds, and 8 in the Kimmeridge Clay. No form is known in the Portland Oolite. The sudden introduction and development of the Belemnitidæ in the Lias calls for and demands much research, the two groups the Ammonitidæ and Belemnitidæ having commenced in such numbers, and the latter declined so rapidly.

Pisces.—43 genera and 132 species of Fish occur in the three divisions of the Lias. 40 genera and 106 species have been described from the Lower Lias, only 2 genera and 2 species are known to occur in the Middle Lias, and 6 genera and 18 species in the Upper. With the exception of 4 genera, *Acrodus*, *Hybodus*, *Lepidotus*, and *Pholidophorus*, which occur in and pass up from the Rhætic bone-bed, all the genera and species enumerated first appeared as denizens of the Liassic seas of Britain. I am not aware of any other Rhætic forms passing to the Lower Lias. Their distribution is extremely local; the mass of the species of the Lower Lias have been obtained from Lyme Regis, and those occurring in the Upper Lias are chiefly from Whitby. The Lower Lias of Lyme Regis has been extensively

opened up and worked for "Cement," the Upper at Whitby for jet and alum-shale; and the working of these three products has undoubtedly led to the making of large collections from the two areas. Yet, largely as these lower beds are worked at Barrow on Soar, only 6 genera and 7 species have hitherto occurred there. But it must be remembered that it is only the very lowest beds that are worked at Barrow, and that only a limited vertical section is exhibited. The genera and species occurring there are *Cosmolepis Egertoni*, *Dapedius orbis*, *Lepidotus serratus*, *Pholidophorus Hastingsiæ*, *P. Stricklandi*, *Pycnodus liassicus*, and *Ptycholepis minor*. Small as is this assemblage, it is the largest known out of the Lyme-Regis area. Thus the 106 Lower-Lias species are nearly all from the cliff-sections and foreshore at Lyme Regis.

The genera most largely represented are the following:—

*Æchmodus....	11	species	all	Lower	Lias.	
*Dapedius	8	,,	,,	,,	,,	
Eugnathus....	12	,,	11	,,	,,	1 Middle, 1 Upper Lias.
Hybodus	10	,,	all	,,	,,	
Leptolepis	6	,,	3	,,	,,	4 Upper Lias.
Pachycormus ..	11	,,	4	,,	,,	8 in Upper.
Pholidophorus..	10	,,	all	,,	,,	

The remaining 36 genera contain only one or a few species each; 23 are represented only by single species.

Very few Lower-Lias species range into the Middle or Upper Lias. *Eugnathus chirotes* is the only form out of the 106 that is common to both Middle and Lower Lias, and *Leptolepis Bronni* and *Pachycormus leptosteus* are the only two species common to the Lower and Upper Lias. No single form occurs in all three divisions. The 18 species of Upper-Lias fish illustrate 6 genera, *Eugnathus* 1 species, *Lepidotus* 3, *Leptolepis* 4, *Macrosemius* 1, *Pachycormus* 8, and *Ptycholepis* 1 species. This almost total dying-out of the Lower-Lias species, without any known or visible unconformity between that division and the succeeding Middle and Upper Lias, has yet to be accounted for. A zoological group so prolific in individuals as the Fishes, and pelagic in habit, must have constituted an important element in the long-continued history of the Lower-Lias deposits. The 36 genera with only a few known species each, and the 23 with only one and few individuals, conclusively show that when we have more exhaustively examined the Lias in its strike through England, these rarer genera will receive large specific additions. Our table shows at a glance the almost complete specific break between the Lower and Middle Lias, and the total change that took place at the close of the formation. The only 4 known Inferior-Oolite forms are *Strophodus magnus*, *S. subreticulatus*, *S. tenuis*, and *Hybodus crassus*, the last genus only being represented in the Lias. The 58 Great-Oolite species stand alone also.

* *Æchmodus* and *Dapedius* are probably one genus.

Reptilia.—7 genera and 44 species are distributed through the Lias. Numerically they are—

Dimorphodon	1	species.
*Ichthyosaurus	11	„
Plesiosaurus	26	„
Scelidosaurus	1	„
Steneosaurus..........	1	„
Teleosaurus	3	„
Pterodactylus	1	„
	44	species.

One genus (*Ichthyosaurus*) and 11 species of the order Ichthyopterygia occur in the Lias, 8 in the Lower, 4 of these in the Middle, and 3 distinct species in the Upper Lias. The latter are *I. longirostris*, *I. crassimanus*, and *I. zetlandicus*, the last 2 being of huge proportions and found only in the Upper Lias of Whitby associated with the equally gigantic Sauropterygians *Plesiosaurus Comptoni* and *P. Cramptoni*. None of the 11 pass to higher beds; and I do not know of any genus or species occurring in either the Inferior Oolite or the Fuller's Earth in Britain. *Plesiosaurus* (Sauropterygia) is illustrated by 26 species in the Lias, 18 of which are Lower, 1 Middle, and 9 Upper. *P. brachycephalus* is Lower and Upper, and *P. costatus* Lower and Middle.

Scelidosaurus.—This remarkable terrestrial Dinosaur has occurred as yet only in the Lower Lias of Charmouth, near Lyme Regis. It was described by Prof. Owen in the Palæontographical Society's volume for 1861–62, and shown by him to be allied to *Iguanodon.* It is believed to have more terrestrial habits than any previously discovered in Liassic deposits.

The Crocodilian genus *Steneosaurus*, belonging to the Mesosuchia of Huxley and allied to *Teleosaurus*, 3 species of *Teleosaurus,* and the Pterosaurian (Ornithosaurian) genus *Pterodactylus* complete the list of Reptilian genera from the Lias. Prof. Sollas has added to our knowledge of the Sauropterygia, through his description of a new species (*Plesiosaurus Conybeari*) from the Lias of Charmouth, and his observations upon *P. megacephalus,* Stutchb., and *P. brachycephalus*, Owen. A most valuable synoptical table of the geographical distribution of the Plesiosaurs is appended to the paper, drawn up by the Rev. G. F. Whidborne, M.A., in which every known British species of Plesiosaur is given, with horizon, locality, and references to literature. The entire paper is a valuable contribution to our knowledge of this group of the Reptilia.

TABLE XXVI.—*Analysis of the Distribution of the Lias Species.*

Classes.		Genera.	Species.	Lower.	Middle.	Upper.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland Oolite.
	Plantæ	12	17	11/15	...	1/2										
	Amorphozoa	1	1	1/1												
	Rhizopoda	23	100	20/84	14/48	10/33										
	Cœlenterata	17	80	13/72	6/8	2/2										
	Echinodermata	20	53	11/15	14/29	8/14										
	Annelida	3	14	1/8	2/5	1/2	2/3									
	Crustacea	14	42	12/33	1/1	6/12										
	Bryozoa	3	6	3/4	1/1	1/1										
	Brachiopoda	16	124	10/36	14/74	11/47	5/8	1/1	1/1							
66 genera and 457 species.	Monomyaria	21	171	18/114	16/60	13/32	8/13	1/1	3/3	...	2/2	2/2	2/2	3/3	2/2	
	Dimyaria	45	286	36/138	34/108	25/69	11/12	5/5	6/6	1/1	2/2					
	Gasteropoda	51	388	41/226	27/136	19/55	6/6	...	1/1	1/1						
Cephalopoda.	Ammonites	1	293	1/173	1/54	1/79	1/3									
	Nautili	1	10	1/6	1/4	1/3										
	Belemnites	1	65	1/21	1/27	1/34										
	Teuthidæ	3	4	1/1	1/1	1/2										
	Pisces	43	132	40/106	2/2	6/18										
	Reptilia	7	44	5/28	2/5	4/13										
	Mammalia	none.														
		281	1830	226/1081	137/563	111/418	33/45	7/7	11/11	2/2	4/4	2/2	2/2	3/3	2/2	

§ 4. Inferior Oolite.

Plantæ.—The Jurassic Plantæ number 63 genera and 192 species, 41 genera and 130 species of which are confined to the Inferior Oolite, not one of them, so far as we know, passing the upper limits of that formation. The remaining 61 species chiefly occur in the Lias, Great Oolite, and Coral Rag, the 7 species in the latter formation being special to it. Almost every species occurs in the estuarine shales and sandstones of the Yorkshire coast, either in the Scarborough or Whitby area. The Middle Shales and Sandstones contain 17 genera and about 50 species, the Lower 13 genera and 30 species. The chief genera are *Otozamites*, 10 species, *Pecopteris*, 22, *Phlebopteris*, 8, *Pterophyllum*, 9, *Sphenopteris*, 16. 15 genera possess only 1 species in each, 15 genera 2 species, 4 genera 3 species, and 2 genera 4 species. This shows us that many of the genera must be established on very slender evidence, which the poverty of the material seems to warrant upon critical examination. In Yorkshire, or the classical locality, the *Equisetaceæ* are illustrated by 2 species, the *Lycopodiaceæ* by 1, the *Filiceæ* by 53 species, the *Cycadaceæ* by 23 species and the *Coniferæ* by 7. There is no other locality in the British Islands where such an assemblage of Jurassic plants can be studied. No complete plant is known in the Forest Marble; but innumerable fragments of coniferous wood occur in the flaggy beds of which it is chiefly composed. Nor is any species known from the Fuller's Earth, Cornbrash, or Kellaways Rock. *Cycadeostrobus sphæricus* is the only Oxford-clay species; and 7 are known from the Coralline beds—*Araucarites Hudlestoni, Bennettites Peachianus, Bucklandia Milleriana, Carpolithes Bucklandi, C. conicus, Yatesia crassa*, and *Y. Joassiana*; *Pinites depressus* is the only species occurring in the Kimmeridge Clay. The so-called Great-Oolite flora is mostly, if not entirely, confined to the underlying fissile Stonesfield Slate or lowest zone of the formation (not present everywhere where the more calcareous overlying Limestones are widely spread).

At Stonesfield in Oxfordshire, and Eyeford and Sevenhampton in Gloucestershire, these "slates" occur as a thin band beneath the true Great or Bath Oolite; and in them, especially near Oxford, an abundant flora has been obtained. Prof. Phillips, in his work 'On the Geology of Oxford and the Valley of the Thames,' enumerates, figures, and describes a large and interesting flora, comprising nearly 40 species; numerically there are—

	Genera.		Species.
Algæ	1	....	1
Filices	6	....	11
Monocotyledoneæ	5	....	6
Cycadaceæ	3	....	9
Coniferæ	2	....	5
Fruits	3	....	4
	20	....	36

The remarkable cones *Aroides Stutterdi*, Carr., and *Kaidacarpum ooliticum*, Carr., are both from these beds at Stonesfield.

This exhausts the flora of the Jurassic rocks proper, or from the base of the Inferior Oolite to the Portland, in the latter of which I know of no recorded plant-remains except wood.

The accompanying small Table (XXVII.) will show the number of genera and species in the 10 divisions of the English and Scotch Oolitic Rocks.

TABLE XXVII.

Number of genera and species, including Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian beds.	Kimmeridge Clay.	Portland rock.
63 191	41 130	...	20 36	...	...	...	1 1	4 7	1 1	

None pass from the Lias to the Inferior Oolite; and none in higher beds are common to more than one deposit.

AMORPHOZOA.—None.

CŒLENTERATA.—*Actinozoa.*—I have stated that 38 genera and 715 species constitute the entire Cœlenterate fauna of the Jurassic rocks. The Lias I have discussed (*vide* Table XXVI., p. 175). The Actinozoa of the Inferior Oolite stand almost alone, its 48 species being, with but few exceptions, confined to it. The only species that pass to higher beds are *Anabacia hemisphærica*, *A. orbulites*, *Comoseris vermicularis*, *Isastræa explanata*, *I. explanulata*, *I. limitata*, *Montlivaltia Delabechei*, *M. tenuilamellosa*, *Stylina solida*, and *Thamnastræa concinna*. Eight of these 10 do not pass beyond the Great Oolite, the species having the longer range being *Isastræa explanata*, which is common, if rightly determined, to both the Inferior Oolite and the Coral Rag, and *Anabacia orbulites*, which occurs in the Forest Marble, Cornbrash, and Corallian beds. Thus, out of the 19 genera and 48 species that commence in the limestones of the Inferior Oolite, 2 genera and 3 species pass to the Fuller's Earth, 5 genera and 7 species to the Great Oolite. Except in the case of the Mollusca, and that in a minor degree (*vide* Table XXXI., p. 188), the community of species between the lowest beds of the Oolitic series and the succeeding 9 horizons is small. With the exception of the *Isastrææ* and *Thamnastrææ*, most of the Corals are simple forms, *e. g.* *Montlivaltia*, *Anabacia*, *Cyclolites*, *Trochocyathus*, &c. In Yorkshire but few species occur in the Inferior Oolite, *Gonioseris angulata*, *G. Leckenbyi*, and *Montlivaltia convexa* being all that are known. We must see the grandly developed Oolites of the Cotteswolds for the more prolific Coralliferous deposits. The Corallian beds of Yorkshire and the South

of England are rich in *Isastrææ* and *Thamnastrææ*. The Coral fauna of the Inferior Oolite, next to the Lower Lias, is the richest in species in the Jurassic rocks. The Lower Lias has yielded 13 genera and 72 species, and the Inferior Oolite 19 genera and 48 species, and not one in common.

The following Table (XXVIII.) expresses the numerical distribution of the Jurassic Actinozoa, from those horizons above the Lias.

TABLE XXVIII.

	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coralline Oolite.	Kimmeridge Clay.	Portland Oolite.
Genera	19	2	15	1	1	...	...	10	...	1
Species	48	4	38	1	1	...	...	14	...	1

ECHINODERMATA.—In the whole of the Jurassic rocks, including the Lias, there are 47 genera and 216 species. The Inferior Oolite contains 22 genera and 51 species, 7 genera and 10 species of which pass to the Fuller's Earth, 8 genera and 11 species to the Great Oolite, 2 genera and 2 species to the Forest Marble, and 3 genera and 5 species to the Cornbrash. The whole Jurassic rocks yield 9 genera and 37 species of Crinoidea; 14 genera and 35 species of Asteroidea; of the Echinoidea, group Endocyclica (or Regular Echinoidea), 12 genera and 92 species; and of the Exocyclica (or Irregular Echinoidea) 7 genera and 37 species.

Crinoidea.—Only 2 species of the known 37 occur in the Inferior Oolite; they are *Pentacrinus Milleri* and *P. Austenii.*

Asteroidea.— *Astropecten* with 3 species, *Goniaster* with 2, *Solaster* and *Stellaster* each with one species, comprise the whole of the Starfishes of the Inferior Oolite. Thus only 7 out of the 35 Jurassic forms have been found in this horizon.

Echinoidea.—17 genera and 40 species out of the 129 known Jurassic species occur in the Inferior Oolite. 11 of the genera and 25 species belong to the group Endocyclica, and 6 genera and 15 species to the Exocyclica. These 2 groups, with the Crinoidea and Asteroidea, are extremely important stratigraphically; their ranges are restricted, and the species afford the safest clue for the purposes of stratigraphical correlation. The accompanying Table (XXIX.) shows the numerical history of the known Echinodermal fauna from the Lower Lias to the close of the Inferior Oolite. The first column contains the genera, and the second column the number of species in the Jurassic rocks, followed by their value in the Lower, Middle, and Upper Lias, and Inferior Oolite.

TABLE XXIX.

	Genera.	Jurassic species.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.
Crinoidea.	Apiocrinus	5	1			
	Actinometra	2				
	Antedon	1				
	Bourgueticrinus	1				
	Extracrinus	3	1	1	1	
	Millericrinus	2				
	Pentacrinus	22	2	9	6	2
	Plicatocrinus	1	1	1		
	Zoocapsa	1	1			
	Rhabdocrinus	2	1			
Asteroidea.	Acroura	1	...	1		
	Astropecten	14	...	2	...	3
	Amphiura	1				
	Aspidura	1	...	1		
	Goniaster	3	...	...	...	2
	Luidia	1	...	1		
	Palæocorina, Ophioderma	5	...	5		
	Ophiolepis	2	1	1		
	Ophiurella	2	...	1		
	Plumaster	1	1	1		
	Solaster	1	...	...	...	1
	Stellaster	1	...	...	...	1
	Tropidaster	1	...	1		
	Uraster	2	...	2		
Endocyclica.	Acrosalenia	13	2	...	1	4
	Cidaris	16	1	1	2	4
	Diplocidaris	2	...	...	1	1
	Glypticus	1				
	Hemicidaris	13	...	...	...	1
	Hemipedina	18	3	1	1	5
	Heterocidaris	1	...	...	...	1
	Magnotia	1	...	...	...	1
	Pedina	2	...	...	...	2
	Polycyphus	2	...	...	...	2
	Pseudodiadema	17	1	1	2	2
	Stomechinus	6	...	...	...	2
Exocyclica.	Clypeus	8	...	...	...	7
	Collyrites	3	...	...	...	2
	Echinobrissus	10	...	...	...	1
	Galeropygus	1	...	...	...	1
	Holectypus	4	...	...	...	2
	Pygaster	5	...	...	...	2
	Pygurus	6	...	...	...	1
		205	16	30	14	50

The 4 groups thus enumerated possess 43 genera and 205 species.

Crinoidea..............	10	genera and	40	species.
Asteroidea	14	,,	36	,,
Echinoidea Endocyclica ..	12	,,	92	,,
Echinoidea Exocyclica ..	7	,,	37	,,
	43	,,	205	,,

A. The Lower Lias Crinoidea	number	7 genera and		7 species.	
„ Middle „ „	„	3	„	11	„
„ Upper „ „	„	2	„	7	„
„ Inferior Oolite „	„	1	„	2	„
B. The Lower Lias Asteroidea	„	2	„	2	„
„ Middle „ „	„	10	„	16	„
„ Upper „ „	„	none		none	
„ Inferior Oolite „	„	4	„	7	„
C. The Lower Lias Echinoidea Endocyclica	„	4	„	7	„
„ Middle „ „ „	„	3	„	3	„
„ Upper „ „ „	„	5	„	7	„
„ Inferior Oolite „ „	„	11	„	25	„
D. The Lower Lias Echinoidea Exocyclica	„	none		none	
„ Middle „ „ „	„	none		none	
„ Upper „ „ „	„	none		none	
„ Inferior Oolite „ „	„	7	„	16	„
Occurrences		59	„	110	„

Annelida.—*Serpula* with 9 species, and *Vermicularia* and *Vermilia* with one species in each, constitute the Annelidan fauna of the Inferior Oolite. *Vermilia sulcata*, *Serpula socialis* and *S. limax* come up from the Lower and Upper Lias. None of the 11 species pass to higher horizons, although 16 species occur in the higher members. All together we know of 45 Jurassic species, the Inferior Oolite containing the greatest number (11).

Crustacea.—The only Decapod known in the Inferior Oolite is *Glyphea rostrata*; and this Macruran ranges up to the Coralline Oolite. The Phyllopod *Estheria concentrica* is confined to this horizon. Doubtless the Decapoda are better represented, as many fragments of undetermined species frequently occur. The Lower Lias contains by far the richest fauna, no less than 12 genera and 33 species.

Bryozoa.—7 genera and 17 species occur in the Inferior Oolite, viz. *Berenicea* 1 species, *Ceriopora* 2, *Diastopora* 9, *Heteropora* 2, *Spiropora* 1, *Stomatopora* ? 1, and *Theonoa* 1 species. *Diastopora cricopora*, Vine, and *D. oolitica*, Vine, occur also in the Fuller's Earth and Great Oolite, where they are associated with *Heteropora conifera* and *H. pustulosa*. The species in the Great Oolite number 31, many of which (7) pass up from the Inferior Oolite. The whole of the known Jurassic Bryozoa from the Lower Lias to the Corallian beds (we know none higher) consist of 19 genera and 51 species.

Brachiopoda.—10 genera and 90 species range through the Inferior-Oolite series. The genus *Terebratula* contains 31 species, *Waldheimia* 13, *Thecidium* 9, and *Rhynchonella* 23; *Lingula* only 1 species; the remaining 5 genera are poorly represented. 5 genera and 8 species connect the Lias and Inferior Oolite; they are *Discina orbicularis*, *Lingula Beanii*, *Rhynchonella plicatella*, *Terebratula infra-oolitica*, *T. sphæroidalis*, *Thecidium Bouchardi*, *T. triangulare*, and *T. Deslongchampsii*. These species are Upper Lias. One species only, *Thecidium triangulare*, ranges through the whole of the Lias and Inferior Oolite.

The numerical value of the genera *Terebratula*, *Waldheimia*,

Thecidium, *Spiriferina*, *Rhynchonella*, and *Discina*, through the whole Jurassic series, is significant. I give their value—

Terebratula has yielded......	67	species.
Waldheimia	44	,,
Rhynchonella..............	64	,,
Spiriferina	18	,,
Discina	18	,,
Thecidium	15	,,

These 6 genera thus yield 226 species. The whole class in the Jurassic rocks numbers 275 species, the 16 known genera being thus represented. The Inferior Oolite possesses 90 species, the largest number known to occur; the Middle Lias 74; and the Lower Lias 36. *Suessia* and *Kingena* have but one species each, and *Megerlia* 2, through all the Jurassic rocks. The tabular distribution I have given at the end of the Jurassic group (Table XLIV.) tells its own tale. The total appearances of the genera and species through time are thus expressed, $_{3}{}^{8}_{7}{}^{8}_{1}$.

Lamellibranchiata.—The Lamellibranchiate or Bivalve fauna of the whole of the Jurassic rocks of Britain now numbers 95 genera and 1368 species. The group Dimyaria possesses 70 genera and 924 species, and the Monomyaria 25 genera and 444 species. The Inferior Oolite, which contains by far the richest fauna in the 13 divisions, has yielded 342 species in both groups (106 Monomyaria and 236 Dimyaria). Possibly no horizon in Britain or on the continent has received so much investigation and scrutiny. The importance of a knowledge of the Mollusca as an aid to stratigraphical geology, the value of species (regard them how we may) as factors in the identification of strata, however different petrologically, and however distant, is familiar to all students. In no group of rocks is more critical knowledge required for the discrimination of contemporaneous or homotaxial strata than in the Jurassic series. In Europe the Molluscan fauna of the Jurassic group is one and the same through each of its subdivisions. The fauna of the Lias of England, Scotland, Ireland, France, and Germany, is almost identical, zone for zone; when the species in the larger genera are critically examined their universality and continuity are remarkable and striking; and the two great palæontological breaks, one at the close of the Lias and the next at the close of the Inferior Oolite, where so great a change took place in the Molluscan fauna, are readily seen in Tables XXVI., XXXI., and XXXIII. The numerical value of the species in certain genera is still more forcibly shown in the accompanying table (XXX.), where 34 of the larger genera are noticed. I append the Lias, as it is the base of the Jurassic system, but will not extend the table here beyond the Cornbrash, where community is greatest, and which completes the Lower Oolite or Lower Jurassic series. Few species pass to the higher members of the Jurassic group.

TABLE XXX.—*Showing the Genera of Lamellibranchs largely represented by Species in the Lower Jurassic Rocks up to the Cornbrash.*

	Chief genera.	Species known.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Cornbrash.	Appearances.
Monomyaria.	Avicula	42	14	3	4	6	1	6	6	40
	Gervillia	33	5	3	4	7	1	11	5	36
	Gryphæa	16	4	4	2	1	...	1	...	12
	Hinnites	14	3	2	3	5	1	3	3	20
	Lima	77	23	10	3	24	4	11	8	83
	Ostrea	59	14	3	2	10	4	10	8	51
	Pecten	90	21	17	5	24	1	17	16	101
	Perna	17	2	...	2	3	...	3	2	12
	Pinna	15	5	4	1	6	1	2	1	20
	Plicatula	17	9	4	...	4	1	2	...	20
		380	100	50	26	90	14	66	49	395
Dimyaria.	Arca	45	6	3	3	12	...	10	1	35
	Astarte	77	5	6	9	24	1	21	7	73
	Cardinia	29	22	10	...	1	...	...	...	33
	Cardium	35	4	2	2	6	...	10	7	31
	Cercomya	18	1	3	1	7	4	6	...	22
	Corbula	15	...	...	...	4	...	4	1	9
	Cucullæa	37	6	2	3	16	4	4	2	37
	Cypricardia	26	6	4	3	5	2	4	2	26
	Cyprina	19	1	...	...	5	...	7	2	15
	Goniomya	15	3	3	3	3	2	5	2	21
	Gresslya	19	4	5	3	3	2	3	1	21
	Leda	31	11	10	3	2	...	2	5	33
	Lucina	24	2	1	...	5	...	6	5	19
	Modiola	44	10	8	7	9	11	14	6	65
	Myacites	33	2	2	4	11	5	7	8	39
	Myoconcha	14	5	...	1	4	1	3	...	14
	Mytilus	25	4	4	1	9	...	2	2	22
	Nucula	19	2	4	4	3	1	2	1	17
	Opis	20	1	2	1	9	...	5	2	20
	Pholadomya	49	8	6	4	11	8	13	10	60
	Pleuromya	23	5	8	5	3	...	...	...	21
	Tancredia	26	5	4	3	10	...	9	...	31
	Trigonia	88	...	1	3	34	2	13	13	66
	Unicardium	12	2	3	3	3	...	3	1	15
		743	115	91	66	199	43	153	78	745

These 34 genera, selected from the 94 that are known, are enumerated on account of their being largely represented; the remaining 60 genera contain species under 14 in number, and therefore need not be noticed, although zoologically many of them are of high importance. *Anomia*, *Crenatula*, *Inoceramus*, *Placunopsis*, *Pteroperna*, and *Trichites* among the Monomyaria, and *Cardita*, *Corbis*,

Cyrena, *Gastrochæna*, *Hippopodium*, *Macrodon*, *Myopsis*, *Pachyrhisma*, *Thracia*, &c. &c. among the Dimyaria, are feebly represented by species, but nevertheless, bathymetrically considered, and with reference to temperature and sedimentation, are of great classificatory value. I compare the class Gasteropoda under its own division; for no less than 76 genera and 1015 species are known in the Jurassic group; they culminate in the Lower Jurassic rocks, the Lower Lias with 226 species, the Inferior Oolite with 240 species, and the Great Oolite with 247 species. In higher Jurassic strata they die away to a few species.

Monomyaria.—25 genera and 444 species of this group are known in the Jurassic rocks. Of these, 15 genera and 106 species belong to the Inferior Oolite, connected only by 13 species with the entire Lias. It is important to know those forms which unite the two horizons, especially as so complete a change in the fauna occurred at the close of the Lias and commencement of the Inferior Oolite. This group, as we have seen, was represented in the Lias strata by $\frac{18}{114}$ in the Lower, $\frac{16}{60}$ in the Middle, and $\frac{13}{32}$ in the Upper Lias, and through 13 of these latter passed into the more calcareous waters of the so-called Inferior Oolite. The connecting species are *Avicula inæquivalvis*, *Gervillia Hartmanni*, *Hinnites abjectus*, *H. velatus*, *Lima bellula*, *L. electra*, *L. punctata*, *Pecten articulatus*, *P. comatus*, *P. demissus*, *Perna rugosa*, *Pinna fissa*, and *P. Hartmanni*. 6 genera and 8 species pass up into the Fuller's Earth, where this latter, in its argillaceous character, is fairly developed, in the Stroud valley, the Bath area, and parts of Somerset: 12 genera and 33 species connect the Inferior and Great Oolite; and no less than 11 genera and 18 species range to the Cornbrash, 10 species avoiding the Forest Marble shallow-water deposits. The faunal recurrence between the Inferior Oolite and Cornbrash is smaller than might be expected, both for this group and the Dimyaria, it being only $\frac{13}{20}$ out of $\frac{47}{236}$ in that division; in the Gasteropoda it is only $\frac{4}{6}$ out of $\frac{41}{240}$. It has been often stated that the two horizons were zoologically closely allied through recurrence. This could only apply to certain areas where the conditions of the Great and Inferior Oolite during deposition were little changed and gradually merged into the locally developed Cornbrash. Community of species between the Inferior Oolite and Cornbrash could hardly have occurred in the Yorkshire basin. The great series of Estuarine sandstones, shales, and iron-stones is broken in sequence between the Dogger and the Cornbrash only by the Grey or Scarboro Limestone and the Millepore-beds, which last, although the lowest of the two, are most nearly allied palæontologically. The long-range species are *Avicula braamburiensis*, *A. Münsteri*, *Gervillia acuta*, *Hinnites abjectus* (Middle Lias to Cornbrash), *Lima duplicata*, *L. pectiniformis*, *Ostrea acuminata*, *O. flabelloides*, *Pecten annulatus*, *P. crenatus*, *P. demissus* (Middle Lias to Kimmeridge Clay), *P. lens*, *P. personatus*, *Perna rugosa*, *Pinna cuneata*, and *Placunopsis inæqualis*. These 16 species, if not as good witnesses as the rarer forms, show that the conditions were such that only minor physical changes affected the fauna

during the intervals of time that occurred between the different horizons. 6 genera and 9 species pass to the Kellaways Rock, and 3 genera and 8 species to the Oxford Clay, viz. *Avicula inæquivalvis, Lima duplicata, L. pectiniformis, Pecten annulatus, P. crenatus, P. demissus, P. lens*, and *P. vimineus*, all moderately deep-sea forms. The Corallian beds contain 4 genera and 6 species, 3 of those just quoted, with *Placunopsis inæqualis, Ostrea solitaria*, and *O. flabelloides*. The Kimmeridge Clay through the persistent shells *Avicula inæquivalvis, Ostrea solitaria, Pecten crenatus, P. articulatus, P. demissus*, and *P. vimineus* keeps up the connexion; but no species of any Jurassic group passes the Portlands.

Dimyaria.—70 genera and 924 species of this group occur in the whole of the Jurassic rocks, and 47 genera and 236 species in the Inferior Oolite. Of these $\frac{12}{28}$ pass to the Fuller's Earth, $\frac{29}{71}$ to the Great Oolite, $\frac{5}{8}$ to the Forest Marble, $\frac{13}{20}$ to the Cornbrash, $\frac{7}{8}$ to the Kellaways Rock, $\frac{2}{2}$ to the Oxford Clay, and $\frac{8}{8}$ to the Corallian beds. The most important genera, or those most largely represented, are:—

Astarte	with	24	species.
Arca	,,	12	,,
Cucullæa	,,	16	,,
Modiola	,,	9	,,
Myacites	,,	11	,,
Mytilus	,,	9	,,
Pholadomya	,,	11	,,
Tancredia	,,	10	,,
Trigonia	,,	34	,,
		136	,,

Thus these 9 genera out of 47, and 136 species out of 236, constitute more than one half of the Dimyarian fauna of the Inferior Oolite; 12 genera possess only one species each, 9 genera two species, and 5 genera three species. These smaller genera with few species often give way under close examination and study. The genera *Cercomya, Dreissena, Pullastra, Ptychomya*, &c., with only one species, like many others, will ultimately be expunged from our lists. Assuming that the species in the above nine prolific genera would probably have a long range in time, we find that the following numbers pass to the Great Oolite—in *Astarte* 10, *Arca* 4, *Cucullæa* only 2, *Modiola* 5 out of 9, *Myacites* only 1, *Mytilus* only 1, *Pholadomya* 4, *Tancredia* 5, and *Trigonia* only 4 out of 34; or 36 species out of the 136 in the above genera are common to the Great and Inferior Oolite. It is easy to account for this on looking into the habits and habitats of the genera, their bathymetrical range, the nature of the sea-bottom and their probable food.

The 20 Cornbrash species that are common to the Inferior Oolite belong to 13 genera—*Anatina, Astarte, Cardium, Corbicella, Goniomya, Gresslya, Homomya, Isocardia, Lucina, Macrodon, Modiola, Quenstedtia*, and *Trigonia*. The Corallian forms yield a single spe-

cies to each of 8 genera—*Trigonia costata*, *Quenstedtia lævigata*, *Myopsis jurassi* (?), *Modiola imbricata*, *Goniomya v-scripta*, *Anatina undulata*, *Arca æmula*, and *Astarte excavata*.

The Bivalves of the Inferior Oolite, numbering 62 genera and 342 species, and from which the higher horizons have been supplied through either direct descent or evolution, cannot receive too much attention; the fact that only $\frac{18}{13}$ Monomyarian forms and $\frac{11}{12}$ Dimyarian come from the Lias below (so far as we know) renders this division of the Lower Oolite of interest.

Gasteropoda.—The whole of the Jurassic Gasteropoda number 76 genera and 1015 species; and those of the Inferior Oolite 41 genera and 240 species. The Lias group holds 51 genera and 388 species ($\frac{41}{226}$ in the Lower, $\frac{27}{136}$ in the Middle, and $\frac{19}{55}$ in the Upper Lias); and now we find that, with the passage of only $\frac{6}{6}$ genera and species to the Inferior Oolite, a totally new Gasteropod fauna, numbering 240, occurs: and, beyond the fact that 22 genera and 40 species are common to it and the Great Oolite, the species are almost confined to the horizon of the inferior division. Only one species (*Alaria Phillipsii*) seems to unite the Fuller's Earth with the Inferior Oolite; no other species has been found, although in the Fuller's-earth rock we should expect to meet with forms that pass over and appear in the Great Oolite, of which (as stated) there are $\frac{22}{40}$ species. The largely represented genera are

Alaria	19	species.
Cerithium	10	,,
Chemnitzia	9	,,
Nerinæa	12	,,
Pleurotomaria ..	47	,,
Trochus	20	,,
Turbo	17	,,

The rarer genera are sparingly represented—*Bulla*, *Ceritella*, *Cirrus*, *Crossostoma*, *Fissurella*, *Melania*, *Onustus*, *Pileolus*, *Pterocera*, *Scalaria*, *Solarium*, and *Spinigera* by one or two species each. 6 genera and 7 species pass to the Forest Marble, and 4 genera and 6 species to the Cornbrash. The 22 genera and 40 species believed to occur in both the Inferior and Great Oolite may be in excess of the truth; the species in Morris and Lycett's memoir on the Mollusca of the Great Oolite (Pal. Soc.) have often had Inferior-Oolite forms referred to them, which would not have been done had we an equally reliable monograph upon the Mollusca of the Inferior Oolite. The $\frac{22}{40}$ genera and species are mostly among the larger genera; yet, after all, it is comparatively a small number, not one genus in four, or one species in ten of the whole univalve fauna. Only $\frac{3}{3}$ pass to the Kellaways Rock, viz. *Pleurotomaria granulata*, *Natica punctura*, and *Alaria trifida*. This last is the only species that passes to the Oxford Clay; and *Turbo funiculatus* is the only known univalve shell common to the Coral Rag and Inferior Oolite. But for the researches of Dr. Lycett in the rich district of Minchinhampton, little or nothing would have

been known of the Great Oolite, the assemblage obtained from that locality exceeding all others united in number of species*.

Cephalopoda.—*Ammonites.*—Only 42 species occur in the Inferior Oolite; yet the Lias holds 293 species, only three of which pass to this horizon—*Harpoceras concavum*, and *Harpoceras radians* and *insigne*; and only one species of the 42 (*Am. fuscus*) passes to higher beds. The restriction is remarkable and, on stratigraphical grounds, important. These 42 species occupy the three zones of *Murchisoni*, *Humphriesianus*, and *Parkinsoni*, these three types definitely holding their position or horizons in the Inferior Oolite; and whether the beds are largely developed or not, their succession is everywhere the same through Britain and on the continent. No group of the Mollusca is so constant in distribution or so valuable to the stratigraphical geologist; but side by side with the Ammonites we may place the Echinoidea as equivalent in value, and equally reliable in stratigraphical geology. Besides the true Ammonites, one species of *Ancyloceras* occurs in the Inferior Oolite †.

The Cotteswold range is classical ground for the clear and definite exposition of the history of the Inferior- and Great-Oolite horizons; it may be said, with the Jura, to elucidate the entire physical and zoological history of the Lower-Oolitic period.

Trigonellites.—These opercula to the shells of the Ammonites have yet to receive much attention; they are now recognized as an important factor in the study of the Ammonitidæ. Waagen, Suess, Neumayr, and others recognize their importance; and when sought for through sections made in the chambers they are much commoner than we once believed. Fine examples have occurred in the Oxford Clay (*T. lamellosus* and *T. politus*), *T. antiquatus* in the Corallian beds, and *T. latus* in the Kimmeridge.

Nautili.—The six species of *Nautilus* that occur in the Inferior Oolite are all confined to it. 21 species are known in the Jurassic rocks; and, with the exception of *N. hexagonus* (which occurs in the Cornbrash, Kellaways Rock, and Corallian beds), all the species are representative and restricted, as much so as the *N. pompilius* of the present day; in other words, omitting the Lias species (included in the 21), the 13 Oolitic species occupy each only one horizon—six species in the Inferior Oolite, three in the Great Oolite, one in the Cornbrash, two in the Kellaways, and one in the Kimmeridge Clay.

Belemnites.—I have stated that 115 species are known in the British Jurassic rocks, but only 16 species occur in the Inferior Oolite; two horizons above this, the Fuller's Earth and Great Oolite, yield only three species each; none are known in the Forest Marble and Cornbrash; 3 occur in the Kellaways Rock, 13 in the Oxford Clay, 4 in the Corallian, and 8 in the Kimmeridge Clay; so that the 115 known species are spread through all the horizons but

* The Walton Collection, now in the Woodwardian Museum, Cambridge, doubtless contains a large number of undescribed species.

† *Ancyloceras annulatum* is the only species in the Inferior Oolite; and the Kellaways and Oxford-Clay species, *A. calloviense*, completes our knowledge of the non-involute forms of the Jurassic Ammonitidæ.

two—the Forest Marble and Cornbrash. The following small Table will illustrate their distribution:—

Lower Lias	21	species.
Middle Lias	27	"
Upper Lias	34	"
Inferior Oolite	16	"
Fuller's Earth	3	"
Great Oolite	3	"
Forest Marble.		
Cornbrash.		
Kellaways Rock	3	"
Oxford Clay	13	"
Corallian beds	4	"
Kimmeridge Clay	8	"
	132	occurrences.

The 115 species make 132 appearances through the whole series of Jurassic strata.

Teuthidæ. The dibranchiate Decapoda of the Jurassic rocks do not number more than six genera, illustrating three families, the Loligidæ, Teuthidæ, and Belemnitidæ. The two first-named families are not represented in the Inferior Oolite; *Acanthoteuthis antiquus* is confined to the Oxford Clay; *Coccoteuthis latipinnis* is essentially Kimmeridge-Clay; *Geoteuthis*, *Beloteuthis*, and *Xiphoteuthis* are Lias genera, numbering four species between them.

Pisces.—*Hybodus crassus*, *Strophodus magnus*, *S. subreticulatus*, and *S. tenuis* (or two genera and four species) are all that we actually know of the Inferior-Oolite fish. No Pycnodont or Lepidotoid form, as we should almost expect, have ever been obtained from the Inferior Oolite. Next to the Lower Lias with its 40 genera and 106 species, comes the Great Oolite, the fish-fauna of which numbers 20 genera and 58 species.

Reptilia none, although 30 genera and 132 species range through the whole Jurassic formation. Three horizons appear to have none, viz. the Inferior Oolite, Fuller's Earth, and Kellaways Rock. 13 genera and 27 species occur in the Great Oolite, 3 genera and 3 species in the Forest Marble, and one species in the Cornbrash. The Oxford Clay contains 13 species, the Corallian rocks 3, the Kimmeridge Clay 43, and the Portlandian 6 species. I state these now, so as to show the census of the Reptilia through the Jurassic rocks; individually they will be noticed hereafter.

Mammalia.—None known.

Table XXXI.—*Analysis and Distribution of the Inferior Oolite Species.*

From Lias.	Classes.		Genera.	Species.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland Oolite.
		Plantæ	41	130									
		Amorphozoa.	none.										
		Rhizopoda.	none.										
		Cœlenterata	19	48	2 3	5 7	1 1	1 1	...	...	1 1		
		Echinodermata	22	51	7 10	8 11	2 2	3 5					
2 3		Annelida	3	11									
		Crustacea	2	2	...	1 1	...	1 1	1 1	...	1 1		
		Bryozoa	7	17	1 2	2 7	1 1	2 2					
5 8		Brachiopoda	10	90	4 9								
8 13	62 genera and 342 species.	Monomyaria	15	106	6 8	12 33	6 10	11 16	6 9	3 8	4 6	3 6	
11 12		Dimyaria	47	236	12 28	29 71	5 8	13 20	7 8	2 2	8 8		
6 6		Gasteropoda	41	240	1 1	22 40	6 7	4 6	3 3	1 1	1 1		
1 3	Cephalopoda.	Ammonites	1	42	1 1								
		Ancyloceras	1	1									
		Nautili	1	6									
		Belemnites	1	16	1 3	1 3							
		Teuthidæ.	none.										
		Pisces	2	4	...	2 2							
		Reptilia	none.										
		Mammalia	none.										
33 45	....		213	1000	35 65	82 175	21 29	35 53	17 21	6 11	15 17	3 6	

§ 5. Fuller's Earth.

Only 51 genera and 110 species occur in this division of the Lower Oolites. Seeing that 35 of the 51 genera and 65 of the 110 species were derived from the Inferior Oolite, and that 80 per cent. of the species occurring are also common to the succeeding Great Oolite, this division has no value, save on physical grounds, and this only over a very limited area; for the Fuller's Earth is by no means universal or even general in its distribution. No Plantæ, Amorphozoa, Crustacea, Nautili, Teuthidæ, or Reptilia occur, *i. e.* 9 of the 19 classes are unrepresented; only 4 species of Corals, 3 Bryozoa, one Gasteropod, 3 species of Belemnites, and 5 species of Ammonites are known. The value, therefore, of the Fuller's Earth as a life-group is almost nil; it is only through the Echinodermata and the Lamellibranchiata that it has position; and 50 per cent. of these came from the Inferior Oolite. The Fuller's Earth is an extremely local formation, the Stroud valley near Gloucester and Bath being the only places where it is extensively developed as a purely argillaceous deposit; in Somersetshire it merges on its strike into a calcareous deposit termed the "Fuller's-earth Rock," which, however, is little richer in fossils than the argillaceous type.

Plantæ.—None.

Amorphozoa.—None.

Cœlenterata.—Only 2 genera and 4 species known; they are *Anabacia hemisphærica*, *Montlivaltia Delabechei*, *M. tenuilamellosa*, and *M. Wrightii*.

Echinodermata.—Out of the 8 genera and 11 species occurring, 7 genera and 10 species came from the Inferior Oolite, leaving only one genus and one species as truly belonging to the Fuller's Earth, viz. *Pygurus Michelini*, which ranges up to the Cornbrash. *Acrosalenia spinosa*, *Clypeus Prattii*, and *Pygurus Michelini* pass to the Great Oolite, the same 3 species to the Forest Marble, and 2 to the Cornbrash.

Annelida.—Only *Serpula triangulata*, *S. lævigata*, and *S. tricarinata* occur; the first two pass to the Great Oolite.

Crustacea.—None.

Bryozoa.—*Diastopora cricopora*, *D. oolitica*, and *Terebellaria ramosissima* constitute the Bryozoan fauna. These same species pass to the Great Oolite, in which division there are 16 genera and 31 known species; few are known or described above the Great Oolite. The whole known Bryozoan fauna of the Jurassic rocks includes 19 genera and 51 species.

Brachiopoda.—Only 4 genera and 14 species occur in this argillaceous deposit. The genus *Terebratula* has yielded 5 species, *Waldheimia* 4, *Rhynchonella* 4, and *Thecidium* one; 4 genera and 7 species pass to the Great Oolite.

Lamellibranchiata.—*Monomyaria*.—More than 50 per cent. of this group of the Bivalvia pass up from the Inferior Oolite; for out of the 9 genera and 15 species occurring, 6 genera and 8 species are common to the two formations; and a large series pass up to the Great Oolite &c.

The long-range forms are *Avicula echinata*, *Gervillia acuta*, *Lima duplicata*, *L. gibbosa*, *Ostrea acuminata*, *O. Sowerbyi*, and *Pecten vagans*. Many species range from the Inferior Oolite to the Corallian beds, but do not appear in the Fuller's Earth. I doubt not many may be found; but not being part of the Fuller's-earth fauna I cannot notice them. 6 genera and 11 species pass to the Great Oolite, 6 genera and 6 species to the Forest Marble; 4 genera and 4 species also occur in the Cornbrash, and $\frac{3}{3}$ in the Kellaways Rock. Analysis need not be carried further, though only one species appears to be common to the Fuller's Earth and the Corallian beds (*Pecten vagans*). 9 species avoided the argillaceous conditions of the Fuller's-earth waters; doubtless it was due to this that so many species in the rich fauna of the Inferior-Oolite sea so suddenly disappeared: the Ammonites dwindled from 42 species to 5, the Gasteropoda from 41 genera and 240 species to *one genus and one species*, and the Lamellibranchs from 62 genera and 476 species to 18 genera and 36 species (a few coming in to swell the number to 66 species), the Dibranchiate Cephalopoda through the Belemnites from 16 species to 3. No *Nautilus* seems to have loved the Fuller's-earth sea; out of the 6 species in the Inferior Oolite none again appeared. This decrease from so prolific a fauna could only be due to physical causes; and probably a locally deep-sea condition prevailed at the close of the Inferior-Oolite period, and with it a corresponding migration of those beings fitted to the new condition of things took place.

Dimyaria.—22 genera and 51 species occur in the Fuller's Earth, $\frac{12}{28}$ of which are Inferior-Oolite forms; so that, as in the group Monomyaria, 50 per cent. passed up from the beds below. These are mostly moderately deep-sea forms, such as *Trigonia*, *Thracia*, *Pholadomya*, *Nucula*, *Myacites*, *Modiola*, *Homomya*, *Cucullæa*, *Anatina*, &c. 19 genera and 36 species passed to the Great Oolite, only $\frac{4}{4}$ to the shallow-water deposits of the Forest Marble, $\frac{10}{14}$ to the Cornbrash, $\frac{6}{9}$ to the Kellaways Rock, $\frac{3}{3}$ to the Oxford Clay, and $\frac{7}{9}$ to the Corallian beds; these occurrences in the higher beds are through long-range species that appear only intermittently, conditions not suiting them.

Gasteropoda.—It seems incredible that a subformation standing between two such prolific horizons as the Inferior Oolite and Great Oolite (the former possessing $\frac{41}{240}$ species, and the latter $\frac{40}{247}$ species) should *yield only one species*; but I know of no other Gasteropod than *Alaria Phillipsii* that bridged over the time occupied in the deposition of the Fuller's-earth clays; and this species, first appearing in the Inferior Oolite, died out in the Great Oolite. Yet $\frac{22}{40}$ species lived on from the Inferior Oolite somewhere during the long change, and appeared again in the Great Oolite; possibly such a total removal or migration of a great group is paralleled nowhere in the British rocks during any period of their long history.

Cephalopoda.—*Ammonites.*—*Am. biflexuosus*, *Am. discus*, *Am. fuscus*, *Am. Herveyi*, and *Am. viator* are the only 5 species known. The zone of *Am. Parkinsoni* did not transmit its rich contents to

the Fuller's Earth; individuals, like species, sparingly occur in these beds. *Am. discus* passes to the Great Oolite and Cornbrash, and *Am. Herveyi* to the latter and the Forest Marble.

Nautili.—None known.

Belemnites.—*B. Blainvillii*, *B. parallelus*, and *B. spinatus* are all that are known of the Dibranchiata. *B. spinatus* passes to the Great Oolite.

Teuthidæ.—None known.

Fishes.—None known.

Reptilia.—None known.

Table XXXII.—*Analysis and Distribution of the Fuller's-Earth Species.*

From Inferior Oolite.	Classes.		Genera.	Species.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portlandian.
		Plantæ.										
		Amorphozoa.										
		Rhizopoda.										
2/3		Cœlenterata	2	4								
7/10		Echinodermata	8	11	3/3	3/3	2/2					
		Annelida..................	1	3	1/2							
		Crustacea.										
1/2		Bryozoa	2	3	2/3	1/1						
4/9		Brachiopoda	4	14	4/7							
6/8	31 genera and 66 species.	Monomyaria	9	15	6/11	6/6	4/4	3/3	2/2	1/1		
12/28		Dimyaria	22	51	19/36	4/4	10/14	6/9	3/3	7/9		
1/1		Gasteropoda	1	1	1/1							
1/1	Cephalopoda.	Ammonites..............	1	5	1/1	1/2	1/2					
		Nautili.										
1/3		Belemnites	1	3	1/1							
		Teuthidæ.										
		Pisces.										
		Reptilia.										
		Mammalia.										
35/65		....	51	110	38/65	15/16	17/22	9/12	5/5	8/10		

§ 6. Great Oolite.

Plantæ.—20 genera and 35 species are distributed through the Great Oolite. The flora of the Inferior Oolite we determined to be 41 genera and 130 species, or nearly four times as prolific; and, be it remembered, there is not a species in common between the two formations, unless *Thuytes expansus* should prove to be so. Thus the Lower Oolites possess 165 species, none of which pass to any higher horizon; and, with the addition of *Cycadeostrobus sphæricus* in the Oxford Clay, 4 genera and 7 species in the Coral Rag, and *Phlebopteris depressus* and *Pinites depressus* in the Kimmeridge, we have the entire flora of the Oolitic rocks; adding the 17 species known in the Lias, the whole Jurassic flora comprises 63 genera and 191 species. *Araucarites Brodiei*, *Aroides Stutterdi*, *Kaidacarpum ooliticum*, and *Stricklandinia acuminata* are amongst the rarer forms occurring; *Palæozamia* and *Thuytes* contain most species; but none of the genera are largely represented. Specifically no two formations, so closely allied through their faunas, could be more distinct through their floras than the Inferior and Great Oolite. No species passes to either the Forest Marble, Cornbrash, or Kellaways Rock, &c., &c.

Amorphozoa (*Spongida*).—Of the 5 genera and 11 species known in all the Jurassic rocks, 4 genera and 9 species occur in the Great Oolite—*Manon* 1 species, *Scyphia* 2, *Spongia* 5, and *Talpina* 1. *Spongia floriceps* appears again in the Corallian beds. The Lias form is *Grantia antiqua*.

Rhizopoda.—None.

Cœlenterata.—15 genera and 38 species have been described from the Great Oolite; most of these are from the Cotteswolds, although Northamptonshire and Lincolnshire have contributed to the large number of species. No higher horizon approaches this in number or variety; none appear in the Kellaways Rock or Oxford Clay (or in the Oxfordian rocks). The group culminates in the Corallian beds, though the number of species is small compared with those of the Great and Inferior Oolites. *Cyathophora*, *Isastræa*, and *Thamnastræa* are the only genera largely represented; the home for *Montlivaltia*, with its 39 species, is the Lower Lias (21) and the Inferior Oolite (11); the remaining 7 species spread through the Great Oolite (3), Forest Marble (3), and the Coral Rag (1). The researches of Dr. Duncan into the Cœlenterate fauna of the Jurassic rocks have greatly added to our intimate acquaintance with this intricate and interesting group.

Echinodermata.—The whole group in the Great Oolite numbers 22 genera and 53 species, nearly as in the Inferior Oolite. I will analyze the groups separately, as they are of much importance to the stratigraphical geologist. Next to the Ammonites in importance, they have received much attention at the hands of French and German palæontologists, especially the former. They fall under four sections or groups, the *Echinoidea* (in two sections), the *Asteroidea* and the *Crinoidea*.

Echinoidea Endocyclica.—8 genera and 27 species belong to this beautiful group in the Great Oolite:—

Acrosalenia	6	species.
Cidaris	3	„
Hemipedina	1	„
Hemicidaris	8	„
Pedina	2	„
Pseudodiadema	5	„
Rhabdocidaris	1	„
Stomechinus	1	„
	27	„

13 genera of the Echinoidea Endocyclica range through the Jurassic rocks, and they are represented by 93 species; very few have long ranges in time. In the group under consideration the genera *Acrosalenia*, *Pedina*, and *Polycyphus* possess species of long duration: they are *Acrosalenia hemicidaroides*, *A. spinosa* (both of which range through the Lower Oolites to the Cornbrash), *Pedina rotata* and *P. Smithii*, *Polycyphus Normanus*; *Hemicidaris Bravenderi* and *Pseudodiadema homostigma* pass also to the Cornbrash. Thus of the 27 species, 7 pass to the horizon named.

Exocyclica.—5 genera and 8 species in this singular group of the Echinoidea occur in the Great Oolite; but the entire Jurassic rocks have yielded 8 genera and 40 species. The Great-Oolite genera are:—

Clypeus	2	species.
Echinobrissus	3	„
Galeropygus	1	„
Pygaster	1	„
Pygurus	1	„
	8	„

Of the 3 genera and 32 species beyond those above named none occur in the Great Oolite; they chiefly belong to the Inferior Oolite; but *Clypeus Mülleri* and *C. Plottii* also occur in the Forest Marble, and *Echinobrissus orbicularis* passes to the Cornbrash and Coral Rag.

Asteroidea.—Only 2 genera (*Astropecten* with 3 species and *Goniaster* with 1) have as yet been detected in the Great Oolite; but 11 genera and 32 species are known in the Jurassic rocks. They are:—

Astropecten	14	species.
Goniaster	3	„
Luidia	1	„
Ophioderma	5	„
Ophiolepis	2	„
Ophiurella	1	„
Plumaster	1	„
Solaster	1	„
Stellaster	1	„
Tropidaster	1	„
Uraster	2	„
	32	„

None of the above 32 species pass to higher beds.

The *Comatulidæ* stand alone, and comprise 5 genera, 3 of which with 4 species occur in the Great Oolite—*Actinometra* with 2 species, *Antedon* and *Amphiura* each with one species.

Crinoidea.—*Apiocrinus*, *Bourgueticrinus*, *Millericrinus*, and *Pentacrinus*, in all 10 species, range through the Great Oolite. 36 are known from the whole Jurassic group.

ANNELIDA.—Only 2 genera (*Serpula* and *Vermilia*) and 7 species occur; the former genus yields 6, the latter 1 species. *Serpula intestinalis* and *S. lacerata* range from the Great Oolite to the Coral Rag inclusive, and the only other species (*S. tetragona*) to the Cornbrash.

CRUSTACEA.—*Glyphea rostrata*, *Pagurus platycheles*, *Palæinachus longipes*, *Pollicipes ooliticus*, and *Prosopon mammillatum* comprise the whole of the Great-Oolite Crustacea. *Glyphea rostrata* is the only species that passes to higher horizons, ranging up to the Coral Rag; the remaining 4 species are restricted. More than half the known Jurassic species (39) are Liassic; 24 genera and 64 species occur in the Jurassic rocks.

BRYOZOA.—19 genera and 51 species (mostly Inferior and Great Oolite) occur through the whole formation. 17 species are Inferior Oolite, and 31 Great Oolite. Only 6 are common to the two horizons, viz. *Diastopora cricopora*, *D. oolitica*, *D. lamellosa*, *D. scobinula*, *Heteropora conifera*, and *H. pustulosa*; and only 3 species pass to higher beds, viz. *Berenicea luciensis*, *Stomatopora dichotoma* (to Cornbrash), and *Terebellaria ramosissima* (occurs in the Forest Marble and Coral Rag). Out of the 19 genera and 51 species known, 16 genera and 31 species occur in this horizon.

BRACHIOPODA.—9 genera and 26 species occur in the Great Oolite. Numerically *Terebratula* is the richest in species (7); *Rhynchonella* has 5, *Waldheimia* 4, *Terebratella* 4, and *Crania* 2; the remaining 4 genera only possess one species each. 4 genera and 7 species pass from the Fuller's Earth to the Great Oolite; and 3 genera and 11 species are common to the Great Oolite and Forest Marble, $\frac{3}{9}$ to the Cornbrash, $\frac{3}{4}$ to the Kellaways, and $\frac{1}{1}$ to the Oxford Clay. No Great-Oolite form passes higher.

LAMELLIBRANCHIATA.—95 genera and about 1360 species in both groups of this class range through the Jurassic Rocks, and almost culminate in the Great Oolite; for above this horizon the whole class of the Lamellibranchiata becomes greatly diminished. In the Forest Marble they number $\frac{28}{63}$, or about 2 species to a genus; in the Cornbrash $\frac{44}{153}$, or $3\frac{1}{2}$ to a genus; in the Kellaways $\frac{29}{85}$, also 3 species to a genus; the Oxford Clay $\frac{30}{74}$, or $2\frac{1}{2}$ to a genus, the Corallian beds $\frac{43}{151}$, the Kimmeridge $\frac{37}{100}$, or about 3 species to a genus.

Monomyaria.—16 genera and 80 species occur in the Great Oolite. The genera are richer in species in the Inferior Oolite, where the known 15 genera contain 106 species. 6 genera and 17 species pass to the Forest Marble, 12 genera and 33 species to the Cornbrash, the superior limit of the Lower Oolite; this number is chiefly made up of species of *Avicula* (5), *Gervillia* (3), *Lima* (5), *Ostrea* (5), *Pecten* (8), and *Placunopsis* (2), all genera with a large number of

species. Those in the intermediate Forest Marble are nearly the same species. To the Kellaways Rock there pass 3 genera and 7 species, to the Oxford Clay 2 genera and 7 species, and to the Coral Rag 2 genera and 6 species; these latter are nearly all the same long-range species.

Dimyaria.—40 genera and 185 species occuring in this division of the Bivalvia (the next highest in the Jurassic rocks to the Inferior Oolite) have been described. The chief genera are:—

Arca	10	species.
Astarte	21	,,
Cardium	10	,,
Modiola	14	,,
Pholadomya	13	,,
Tancredia	9	,,
Trigonia	13	,,

These are the only 7 out of the 40 possessing 9 or more species; 9 genera yield only one species each, 8 have only 2, 6 have 3, &c., &c., thus showing that well-determined genera are of high significance although only feebly represented. Numbers when stated alone may not to some appear to have value; but those accustomed to study any given fauna, at once appreciate the value of genera and species from their numerical representation. 19 genera and 36 species pass up from the Fuller's Earth to the Great Oolite; 10 genera and 16 species range into the Forest Marble, 20 genera and 44 species to the Cornbrash, and 10 genera and 10 species to the Corallian beds.

Gasteropoda.—40 genera and 247 species enrich this division of the Lower Oolitic rocks. The greater number of these species have been critically described by Messrs. Lycett and Morris in their monograph upon 'The Great Oolite Mollusca' from Minchinhampton, near Stroud*. The Appendix and Supplement by Dr. Lycett in 1863† greatly add to the previously known species, embracing, in addition to the Great-Oolite fauna, descriptions of the Mollusca of the Stonesfield Slate, Forest Marble, and Cornbrash. In this great work the authors describe 265 species of Gasteropoda, and from 260 to 265 species of Lamellibranchiata. The Great-Oolite fauna of the Minchinhampton beds is not local or exceptional, although so rich, but represents a characteristic series of Mollusca occurring in other and distant localities on the same geological horizon. The researches of Mr. Whiteaves in Oxfordshire have shown that out of about 140 species in this area 114 are common to the Minchinhampton beds; this also is confirmed in Somersetshire and Wiltshire through the collection made by Mr. Walton: these latter comparisons refer to the more minute fauna of both areas. We look to France and the researches of Buvignier for a fauna equal in richness and variety to that of the classical district

* Palæontographical Society's memoirs for the years 1850, 1853, 1854, 1861, 1863.

† *Ib.* 1863, Suppl. Monog. on the Mollusca from the Stonesfield Slate, Great Oolite, Forest Marble, and Cornbrash.

of Minchinhampton. Only one genus with one species unites the Fuller's Earth to the true Great Oolite, and only 16 genera and 31 species pass to the Forest Marble, and 14 to the Cornbrash out of the 247; so that the Great-Oolite Univalve fauna is distinctive and characteristic.

CEPHALOPODA. *Ammonites.*—Seven species occur, and six of these are peculiar; they are *Am. arbustigerus*, *Am. discus*, *Am. gracilis*, *Am. micromphalus*, *Am. Morrisii*, *Am. subcontractus*, and *Am. Waterhousii*; all but *Am. discus*, which passes to the Cornbrash, are confined to the horizon of the Great Oolite.

Nautili.—*N. Baberi*, *N. dispansus*, and *N. subcontractus* are essentially Great Oolite, and all that are known.

Belemnites.—*B. aripistillum*, *B. Bessinus*, and *B. spinatus* are all that are known; the two first named are confined to the Great Oolite.

Teuthidæ.—None.

PISCES.—20 genera and 58 species occur, and all except two are peculiar. The exceptions are *Strophodus magnus* and *S. tenuis*, which occur in and come up from the Inferior Oolite: so that 56 species commence in and are confined to this horizon. I give the genera and number of species as follows:—

Acrodus	2	species.
Amblyurus	1	,,
Asteracanthus......	2	,,
Belonostomus	2	,,
Caturus	1	,,
Ceratodus	1	,,
Ctenolepis	1	,,
Ganodus	10	,,
Gyrodus	2	,,
Hybodus	8	,,
Lepidotus	2	,,
Leptacanthus	2	,,
Nemacanthus	2	,,
Pholidophorus......	2	,,
Pristacanthus	1	,,
Pycnodus..........	12	,,
Sauropsis..........	1	,,
Scaphodus	1	,,
Sphenonchus	1	,,
Strophodus	4	,,
	58	,,

The Hybodonts, Pycnodonts, and Ganoidei are numerically the richest in genera. The only known species occurring in the Forest Marble is *Asteracanthus Stutchburii*, a species long believed to belong to the Lias. I am not aware of any Pycnodonts, Hybodonts, or Strophodonts occurring in the Forest Marble. The Cornbrash has yielded *Asteracanthus acutus* and *Isodius leptognathus*; I know of no other forms.

The Kellaways Rock has a solitary species, *Strophodus radiato-punctatus*. The Oxford Clay yields 4 species, the Coralline Oolite 3, the Kimmeridge Clay 11 genera and 14 species, and the Portland Oolite 4 genera and 5 species, which I will refer to under their respective formations.

Reptilia.—13 genera and 27 species, both terrestrial and marine, occur in the Great-Oolite strata. Some of the most gigantic forms that have inhabited the globe lived during the time when the beds composing the Great Oolite were being deposited; but the position of the land on which the huge terrestrial Dinosaurs lived we have yet to determine. The 13 known genera are:—

Testudo.	Rhamphorhynchus.
Chelys.	Megalosaurus.
Teleosaurus.	Ceteosaurus.
Streptospondylus.	Cardiodon.
Ichthyosaurus.	Oolithes (?).
Plesiosaurus.	Lacerta.
Pterodactylus.	

Chelonia.—Regarding these zoologically, the Chelonia are represented by *Testudo Stricklandi*, Phill., and *Chelys Blakii* from the Stonesfield Slate, the former believed to be a terrestrial species; scutes and a short phalangeal bone are all that are known. The second genus, *Chelys*, was found in the Stonesfield beds in 1863.

Crocodilia.—*Teleosaurus*, *Streptospondylus*, and *Steneosaurus* all occur in the Jurassic rocks; but only the two former genera in the Great Oolite. *Steneosaurus*, with one exception (*S. brevior*) in the Upper Lias, is a Kimmeridgian genus, in which five species occur. *Streptospondylus Cuvieri* and an unnamed species occur in the Great Oolite or Stonesfield Slate, and the same in the Oxford Clay.

Prof. Owen divides the Crocodilia into three suborders, the *Procœlia*, *Amphicœlia*, and *Opisthocœlia*. Prof. Huxley proposes a more elaborate classification for the Crocodilia: 1. The *Parasuchia*, 2. the *Mesosuchia*, and 3. the *Eusuchia*. Only his second group, the *Mesosuchia*, concerns us, in which are placed the genera *Streptospondylus* and *Teleosaurus*, both of which occur in the Great Oolite. (*Pelagosaurus*, *Teleidosaurus*, *Macrospondylus*, and *Metriorhynchus* are not known as British.) The amphicœlian genus *Teleosaurus* is represented by 3 species—*T. brevidens*, *T. cadomensis*, and *T. subulidens*, occurring in the Stonesfield Slate and in the higher calcareous divisions of the Great Oolite at Enslow Bridge near Oxford. The extinct amphicœlian Crocodiles are confined entirely to the Mesozoic period. Palæontologically considered they are the most important group of the order Crocodilia; they are also its most ancient representatives. The Trias yields the earliest types through *Stagonolepis* and *Belodon*. The home of the amphicœlian Crocodiles is in the Jurassic series, in which the most important genera are *Teleosaurus* and *Streptospondylus*.

Ichthyopterygia (Owen), *Ichthyosauria* (Huxley).—2 species occur, *Ichthyosaurus advena* and *I. erraticus*, in the Stonesfield Slate and beds above. The Ichthyopterygia include only this one genus. The remains

are scattered, together with shells, corals, Echinoidea &c., over the surface of the slates.

Sauropterygia, Owen, *Plesiosauria*, Huxley.—Only one species (*Plesiosaurus serraticus*) known, associated with the Ichthyosauria in the Stonesfield Slate. The gigantic Upper-Lias forms from near Whitby surpass in size those of any other locality or formation. Although 45 species are known in Britain only the one species named occurs in the Great Oolite; 5 are found in the Corallian beds, 12 in the Kimmeridge Clay, and 2 in the Portlandian beds. *Pliosaurus* is not known below the Oxford Clay and Corallian rocks.

Pterosauria (*Ornithosauria*, Seeley).—This group of flying Reptilia exclusively belongs to the Mesozoic epoch. The genera *Pterodactylus*, *Dimorphodon*, and *Rhamphorhynchus* all occur in Britain—*Dimorphodon* and *Pterodactylus* in the Lower Lias, and *Rhamphorhynchus* and *Pterodactylus* in the Great Oolite; the former represented by 3 species—*R. Bucklandi*, *R. Prestwichii*, and *R. depressirostris*; the latter by 3 species—*P. Aclandi*, *P. Duncani*, and *P. Kiddii*.

Dinosauria (*Ornithoscelida*, Huxley).—The whole group is exclusively Mesozoic, ranging from the Triassic to the Cretaceous formations. The most important genera are *Iguanodon*, *Hylæosaurus*, *Megalosaurus*, *Ceteosaurus*, and *Compsognathus*. This order underwent immense development in the Jurassic and Cretaceous periods; and the Cretaceous genera *Hypsilophodon*, *Iguanodon*, *Polacanthus*, *Titanosaurus*, *Acanthopholis*, &c. attest their importance, associated as they are zoologically with *Megalosaurus* and *Ceteosaurus*, which occur in the Jurassic rocks.

Megalosaurus.—The great carnivorous Lizard *Megalosaurus* finds its true home in the Great Oolite*. Only one species seems to have been named, but we possess evidence of two more. *Megalosaurus Bucklandi* possibly ranges from the Lower Lias to the Kimmeridge Clay.

Ceteosaurus.—5 species of this wonderful Dinosaurian genus have been described; the grandest form, *C. oxoniensis*†, is from the Great Oolite of Enslow Bridge near Oxford. The other species are *C. glymptonensis*, *C. longus*, Owen, *C. medius*, Owen, and a new species described by Dr. Hulke, from the Kimmeridge Clay. *C. longus* is of Portland age, but doubtful in the Great Oolite.

Oolithes.—Are believed to be ova either of Chelonia or Crocodilia. *O. bathonica*, so named by Professor Buckman.

The following grouping will show the distribution of the Great-Oolite Reptilia, and the numerical value of the species:—

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* *Vide* Phillips, 'Geol. of Oxford and Valley of the Thames,' pp. 196–219, for the complete history of *Megalosaurus*.

† *Vide* 'Geol. of Oxford and Valley of the Thames,' pp. 245–294.

Chelonia	Testudo	1	species.
	Chelys	1	"
Crocodilia......	Teleosaurus	3	"
	Streptospondylus ..	2	"
Ichthyosauria ..	Ichthyosaurus	2	"
Plesiosauria	Plesiosaurus......	1	"
Pterosauria	Pterodactylus	3	"
	Rhamphorynchus..	3	"
Dinosauria	Megalosaurus	3	"
	Ceteosaurus	5	"
	Cardiodon........	1	"
	Oolithes	1	"
	Lacerta..........	1	"
		27	"

MAMMALIA.—4 genera with 6 species have been recognized in the Stonesfield Slate of Stonesfield, namely, *Amphilestes, Amphitherium, Phascolotherium*, and *Stereognathus*. These were the first discovered proofs of the existence of warm-blooded quadrupeds in the British strata; since then *Microlestes antiquus* and *Hypsiprymnopsis*? have been discovered in the Upper Triassic rocks. *Microlestes* finds its nearest ally amongst existing mammals in the marsupial and insectivorous *Myrmecobius*, or Banded Anteater, of Australia; teeth only of *Microlestes* have as yet occurred. Prof. Owen divides the Marsupialia into two primary groups, the *Diprotodontia* and *Polyprotodontia*. The living Diprotodonts embrace the herbivorous *Macropodidæ, Phascolomys, Hypsiprymnus*, and the *Phalangistidæ*. The Polyprotodonts *Perameles, Didelphidæ, Myrmecobius, Dasyurus*, and *Thylacinus* are carnivorous. Both these habits may also be ascribed to the fossil forms, the characters of the teeth in the fossil as well as in the living forms being conclusive evidence.

Amphitherium, from the Stonesfield Slate, is related to the living *Myrmecobius*. *Amphilestes* and *Phascolotherium* were also insectivorous Marsupials, *Phascolotherium* finding its nearest living ally in the American Opossums. *Stereognathus* stands in a dubious position; possibly it may be "placental."

The association of the Marsupialia then, as now, with a peculiar land flora (Araucariæ and Cycadeæ), and the presence in the Jurassic seas of the Cestraciontidæ and the Molluscan genus *Trigonia* (now exclusively confined to the Australian seas), tend to show that in England at the time of the deposition of the Great Oolite or the Stonesfield Slate there must have been both a fauna and a flora resembling in a remarkable manner those now occurring in Australia.

For the Analysis of the Great-Oolite species see Table XXXIII. p. 200.

Table XXXIII.—*Analysis and Distribution of the Great-Oolite Species.*

From Fuller's Earth.	Classes.		Genera.	Species.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian beds.	Kimmeridge Clay.	Portland Oolite.
		Plantæ	20	35							
		Amorphozoa	4	9	...	...	...	...	$\frac{1}{1}$		
		Rhizopoda (none).									
		Cœlenterata	15	38	$\frac{1}{1}$	$\frac{4}{5}$					
$\frac{3}{3}$		Echinodermata	22	53	$\frac{4}{6}$	$\frac{7}{10}$					
$\frac{1}{2}$		Annelida	2	7	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{2}$		
		Crustacea	5	5	...	$\frac{1}{1}$	$\frac{1}{1}$	...	$\frac{1}{1}$		
$\frac{2}{3}$		Bryozoa	16	31	$\frac{1}{1}$	$\frac{2}{2}$	...	...	$\frac{1}{1}$		
$\frac{4}{7}$		Brachiopoda	9	26	$\frac{3}{11}$	$\frac{3}{9}$	$\frac{3}{4}$	$\frac{1}{1}$			
$\frac{6}{11}$	56 genera and 265 species.	Monomyaria	16	80	$\frac{6}{17}$	$\frac{12}{33}$	$\frac{3}{7}$	$\frac{2}{7}$	$\frac{2}{6}$	$\frac{2}{2}$	
$\frac{19}{36}$		Dimyaria	40	185	$\frac{10}{16}$	$\frac{20}{44}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{10}{10}$		
$\frac{1}{1}$		Gasteropoda	40	247	$\frac{16}{31}$	$\frac{9}{14}$	$\frac{2}{2}$	$\frac{2}{2}$	$\frac{1}{1}$		
$\frac{1}{1}$	Cephalopoda.	Ammonites	1	7	...	$\frac{1}{1}$					
		Nautili	1	3							
$\frac{1}{1}$		Belemnites	1	3							
		Teuthidæ (none).									
$\frac{2}{2}$		Pisces	20	58							
		Reptilia	13	27							
		Mammalia	4	6							
$\frac{40}{67}$		....	229	820	$\frac{42}{84}$	$\frac{60}{120}$	$\frac{11}{16}$	$\frac{7}{12}$	$\frac{17}{22}$	$\frac{2}{2}$	

§ 7. Forest Marble.

Plantæ.—None, or only fragments of wood.

Amorphozoa.—None.

Cœlenterata.—The only species known in the Forest Marble is *Anabacia orbulites*, and the same passes up to the Cornbrash.

Echinodermata.—6 genera and 10 species occur, $\frac{4}{6}$ of which had previously appeared in the Inferior and Great Oolites; these connecting species are *Acrosalenia pustulata*, *A. spinosa*, *Apiocrinus Parkinsoni*, *Cidaris bradfordiensis*, *Clypeus Mülleri*, and *C. Plottii*. The remaining 4 species are strictly Forest-Marble species, and are *Apiocrinus elegans*, *Astropecten Huxleyi*, *A. Phillipsii*, and *Hemicidaris*

alpina. One species, *Acrosalenia spinosa,* passes to the Cornbrash; and I know of no other species common to the two horizons.

Annelida.—*Serpula intestinalis* is the only species occurring in the Forest Marble, and this form has the longest continuous range of any in the Jurassic rocks. It has been found in 6 horizons, viz. from the Great Oolite to the Coral Rag inclusive. 11 species occur in the Inferior Oolite, 3 in the Fuller's earth, and 7 in the Great Oolite.

Crustacea.—None.

Bryozoa.—*Spiropora straminea* and *Terebellaria ramosissima* are the only two species occurring in the Forest Marble. The former occurs in the Inferior Oolite, and passes to the Cornbrash; the latter occurs in the Fuller's Earth, Great Oolite, and Coral Rag. 31 species are known in the Great Oolite, and 17 in the Inferior Oolite. We should hardly expect to find this class well represented in the Forest Marble or the Fuller's Earth, the argillaceous nature of the latter and the fragmentary or triturated nature of the former being highly unfavourable for their development or preservation.

Brachiopoda.—*Terebratula, Waldheimia,* and *Rhynchonella* are the only 3 genera in the Forest Marble, and they include 10 species, viz. *Terebratula* 4, *Waldheimia* 3, and *Rhynchonella* 3. 8 of the 10 species are common to the Cornbrash, and 3 to the Kellaways Rock.

Lamellibranchiata. *Monomyaria.*—9 genera and 24 species occur in the Forest Marble. The genus *Pecten* only is comparatively largely represented, but sparingly so as compared with other formations. 9 species represent this prolific genus. Out of the $\frac{9}{24}$ occurring here, $\frac{6}{17}$ have appeared before, and 7 of the 9 genera and 14 of the species pass to the Cornbrash; so that in reality only 4 genera and 4 species belong specially to the Forest Marble: they are *Gervillia Waltoni, Ostrea wiltonensis, Pecten divaricatus,* and *Perna obliqua.* The poverty of species in certain groups, and total want of representation of many whole classes in the Forest Marble is readily accounted for through the nature of the deposit and the mode of its accumulation; for, as we shall see, no *Nautili*, no *Pisces*, no *Reptilia*, and no *Mammalia* have yet occurred with all the research that this group has undergone.

Dimyaria.—19 genera and 39 species have been obtained from the Forest Marble; $\frac{10}{16}$ are also in the horizons below, and $\frac{11}{19}$ pass to the Cornbrash. The two chief genera are *Astarte* and *Trigonia.* The former possesses 8 species and the latter 6; 12 genera yield only 1 species each, thus clearly showing the change in the deposits at the termination of the deeper-sea condition of the Great Oolite, in which no less than 40 genera and 185 species are known. This paucity is striking and in conformity with the physical conditions that prevailed. *Pholadomya, Myacites, Modiola, Lucina, Goniomya, Arca, Cardium, Ceromya,* and *Cyprina,* all moderately deep-sea forms, are almost totally unrepresented, yet the succeeding Cornbrash has yielded 33 genera and 98 species.

Gasteropoda.—19 genera and 43 species have been recorded from

this horizon, mostly from the counties of Gloucester, Somerset, and Dorset. 16 genera and 31 species pass from the Great Oolite and unite the two subformations; but only 2 species, *Patella cingulata* and *Actæonina Luidii*, pass to the succeeding Cornbrash; none to the Kellaways Rock. 41 species of the Gasteropoda, therefore, do not range beyond the Forest Marble; overlapping forms from the Great Oolite to the Cornbrash, and not appearing in the Forest Marble, number 9 genera and 14 species. No genus out of the 19 occurring in this group possesses more than 4 species, and 10 only 1. The same paucity occurs in the Lamellibranchiata.

Cephalopoda. *Ammonites.*—*Ammonites Herveyi* is the only species really known in the Forest Marble, and this species also occurs in the Cornbrash. *Am. radisensis*, D'Orb., is doubtfully referred to the Forest Marble.

Nautili.—None known.

Belemnites.—None known.

Pisces.—*Asteracanthus Stutchburii*, erroneously placed for many years in the Lower Lias.

Reptilia.—*Bothriospondylus robustus* and remains of *Streptospondylus*, belonging to the Crocodilia, and the Dinosaur *Megalosaurus Bucklandi* comprise all we know of the Reptilia in the Forest Marble.

Mammalia.—None known.

For the Analysis of the Forest-Marble species, see Table XXXIV. page 203.

§ 8. Cornbrash.

This uppermost horizon of the Lower Oolite is rich only in the Echinodermata, Lamellibranchiata, and Gasteropoda.

Plantæ.—None known.

Amorphozoa.—None known.

Cœlenterata.—*Anabacia orbulites*, one of the Fungidæ, is the only species known to occur in the Cornbrash. This species ranges from the Inferior Oolite direct to the Cornbrash.

Echinodermata.—12 genera and 23 species may be said to range through England, the persistency of the Cornbrash from Dorsetshire to Yorkshire being such as to render it a continuous band, never many feet in thickness anywhere. The 12 genera are sparingly represented. With the exception of the Asteroid *Ophiurella Griesbachii*, the whole of the class belong to the Echinoidea. 4 genera—*Echinobrissus* 3 species, *Holectypus* 1, *Pygaster* 2, and *Pygurus* 1—represent the group Exocyclica; and *Acrosalenia* 4 species, *Hemicidaris* 1, *Hemipedina* 2, *Pedina* 2, *Polycyphus* 1, *Pseudodiadema* 4, and *Stomechinus* 1 species, belong to the Endocyclica. No Crinoidal remains have hitherto been recorded. One species (*Acrosalenia spinosa*) passes up from the Forest Marble; and 2 species (*Echinobrissus orbicularis* and *E. dimidiatus*) pass to the Coral Rag. Thus 20 species are restricted to this uppermost member of the Lower Oolite.

TABLE XXXIV.—*Analysis and Distribution of the Forest-Marble Species.*

From Great Oolite.		Classes.	Genera.	Species.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland Oolite.
		Plantæ, Protozoa, Rhizopoda (none).								
$\frac{1}{1}$		Cœlenterata	1	1	$\frac{1}{1}$					
$\frac{4}{6}$		Echinodermata	6	10	$\frac{1}{1}$					
$\frac{1}{1}$		Annelida	1	1	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$		
		Crustacea (none).								
$\frac{1}{1}$		Bryozoa	2	2	$\frac{1}{1}$	...	...	$\frac{1}{1}$		
$\frac{3}{11}$		Brachiopoda	3	10	$\frac{3}{8}$	$\frac{3}{3}$				
$\frac{6}{17}$	28 genera and 63 species.	Monomyaria	9	24	$\frac{7}{14}$	$\frac{3}{6}$	$\frac{2}{5}$	$\frac{1}{2}$		
$\frac{10}{16}$		Dimyaria	19	39	$\frac{11}{19}$	$\frac{3}{3}$	$\frac{2}{2}$	$\frac{2}{2}$		
$\frac{16}{31}$		Gasteropoda	19	43	$\frac{2}{2}$					
	Cephalopoda.	Ammonites	1	2	$\frac{1}{1}$					
		Nautili, Belemnites, Teuthidæ (none).								
		Pisces	1	1						
		Reptilia	3	3						
		Mammalia (none).								
$\frac{42}{84}$		....	65	136	$\frac{28}{48}$	$\frac{10}{13}$	$\frac{5}{8}$	$\frac{5}{6}$		

ANNELIDA.—The Tubicola, through the genus *Serpula* with 5 species, include all the known Annelida; only 1 species is truly Cornbrash, viz. *S. quadrata*. *S. vertebralis* occurs in the Oxford Clay also; and *S. intestinalis* ranges from the Great Oolite to the Coral Rag inclusive. The intricate distribution of the 45 species of *Serpula* through the Jurassic rocks is not easy to trace. The largest number of species, 11, occurs in the Inferior Oolite; the Lower Lias contains 8, the Corallian rocks 7, the Great Oolite 7, and the Middle Lias 6; the remaining 8 horizons are variously represented. *Vermicularia* and *Vermilia* are not known in this subdivision of the Jurassic series.

CRUSTACEA.—*Glyphea Birdii*, *G. rostrata*, and *G. scabrosa* are the only 3 species of Crustacea known in the Cornbrash. *G. rostrata*

ranges from the Inferior Oolite to the Corallian rocks. *G. scabrosa* is entirely confined to the Cornbrash, and is a Yorkshire form.

BRYOZOA.—*Berenicea diluviana*, *B. luciensis*, *Hippothoa Smithii*, *Spiropora straminea*, and *Stomatopora dichotoma* are the 4 genera and 5 species that occur in the Cornbrash. *Hippothoa Smithii* is the only species truly belonging to this horizon. The other 4 named species reach the Cornbrash from lower beds. 19 genera and 51 species in all occur in the Jurassic rocks. 31 species are in the Great Oolite, 17 in the Inferior Oolite.

BRACHIOPODA.—*Terebratula* with 5 species, *Waldheimia* with 8, *Rhynchonella* with 5, and *Discina* with 1, comprise all that are known in the Cornbrash. *Waldheimia obovata*, *W. ornithocephala*, *Terebratula coarctata*, *T. intermedia*, and *T. obovata*, $= \frac{2}{5}$, pass to the Kellaways Rock; no Lower Oolite form passes to any higher horizon.

LAMELLIBRANCHIATA. *Monomyaria.*—11 genera and 55 species occur, chiefly made up of species belonging to the genera *Avicula* (6 species), *Gervillia* (5), *Lima* (8), *Ostrea* (8), and *Pecten* (16); the remaining 6 genera number but few species. 7 genera and 14 species pass to the Kellaways Rock; and the same number bridge over the change occurring between the Forest Marble and Cornbrash, so that the peculiar or confined species are few. Those that pass direct to the Kellaways Rock are *Avicula braamburiensis*, *Gervillia aviculoides*, *Lima duplicata*, *L. pectiniformis*, *Ostrea flabelloides*, *O. Sowerbyi*, *Pecten annulatus*, *P. armatus*, *P. demissus*, *P. fibrosus*, *P. inæquicostatus*, *P. lens*, *P. vagans*, *Perna rugosa*, and *Placunopsis inæqualis*. The only restricted species, so far as we know, are *Hinnites gradus*, *H. gradatus*, *Lima helvetica*, *L. rigidula*, *Ostrea spatiosa*, *Pecten anisopleurus*, *P. cingulatus*, and *P. rushdenensis*. Only 3 of the genera pass to the Oxford Clay—*Gervillia*, *Lima*, and *Pecten* (*Gervillia aviculoides*, *Lima duplicata*, *L. pectiniformis*, *Pecten annulatus*, *P. arenatus*, *P. demissus*, *P. fibrosus*, *P. lens*, and *P. vagans*). 4 genera with 13 species pass to the Coral Rag or Corallian beds.

Dimyaria.—33 genera and 98 species range through England. *Pholadomya* and *Trigonia* are the only two largely represented genera, the former by 10 species, the latter by 13. *Modiola*, *Myacites*, *Astarte*, and *Cardium* have 7 species each. 14 genera yield only 1 species each; and 11 only 2. Either want of research or extreme rarity (which is hardly probable) must account for the paucity of individuals. The Cornbrash receives from the Forest Marble 11 genera and 19 species; and 12 genera and 27 species pass to the succeeding Kellaways Rock. Only 8 genera and 12 species are strictly confined to the Cornbrash; and 8 genera and 16 species first appear in it. Those strictly confined to the Cornbrash, so far as we at present know, are:—*Astarte Leckenbyi*, *Cardium latum*, *Leda rostralis*, *L. variabilis*, *Lucina Beanii*, *Myacites uniformis*, *Opis Leckenbyi*, *O. scarburgensis*, *Sanguinolaria parvula*, *Trigonia cassiope*, *T. scarburgensis*, and *T. tripartita*.

Although the Cornbrash makes no physical or stratigraphical

feature in Yorkshire, yet palæontologically it is of much importance. Leckenby, Lycett, Hudleston, and others have written its history through the fossils collected. It physically marks the termination of the Upper Estuarine series of the Lower Oolite, constituting, with the Dogger, Grey Limestone, and Millepore-bed, four marine episodes in the greatly developed Estuarine group of Yorkshire. 7 genera and 7 species also pass to the Oxford Clay, many species, however, avoiding this argillaceous deposit, and reappearing in the higher Corallian beds, where 9 genera and 17 species have been observed.

Gasteropoda.—20 genera and only 28 species have as yet been described from the Cornbrash. 14 of the 20 genera are represented only by 1 species each, 4 by 2 species, and the remaining 2 by 3 species each. We might almost say that here specific representation has no value. 5 genera and 6 species pass to the Kellaways Rock, 3 genera and 3 species to the Oxford Clay, and 4 genera and 4 species to the Corallian beds. 9 genera and 11 species are entirely confined to the Cornbrash. It is essential that I should name these 11 species; they have value now, but in time may not. They are:—*Actæonina scarburgensis*, *Amberlya armigera*, *Ceritella costata*, *Nerinæa granulata*, *Nerita granulata*, *Neritopsis d'Archiaci*, *N. Guerrei*, *Purpuroidea ornata*, *Trochus strigosus*, *Chemnitzia vetusta*, and *C. vittata*. Only 2 species connect the Forest Marble and Cornbrash, viz. *Actæonina marginata* and *Patella cingulata*. 6 species pass to the succeeding Kellaways Rock in Yorkshire; these are *Pleurotomaria granulata*, *Natica* (or *Littorina*) *punctata*, *Amberlya ornata*, *Dentalium entaloideum*, *Alaria trifida*, and *A. bispinosa*. There is no more unsatisfactory group of Mollusca in the Cornbrash than the Gasteropoda. There are few species and few individuals, and these are seldom well preserved.

Cephalopoda. *Ammonites.*—*Ammonites discus*, *A. Herveyi*, and *A. macrocephalus* constitute the Ammonitidæ. *A. macrocephalus* ranges into the Kellaways Rock and Oxford Clay.

Nautili.—*Nautilus hexagonus* is the only species; it occurs also in the Kellaways Rock and Corallian beds.

Belemnites.—No Dibranchiata known.

Pisces.—*Asteracanthus acutus* and *Isodius leptognathus* constitute all the fishes known in the Cornbrash.

Reptilia.—Remains of *Megalosaurus Bucklandi* occur, and this is the only form known.

Mammalia.—None known.

For the Analysis of the Cornbrash species, see Table XXXV. p. 206.

Table XXXV.—*Analysis and Distribution of the Cornbrash Species.*

From Forest Marble.		Classes.	Genera.	Species.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland Oolite.
		Plantæ, Amorphozoa, Rhizopoda (none).							
1/1		Cœlenterata	1	1					
1/1		Echinodermata	12	23	...	...	1/2		
1/1		Annelida.................	1	5	1/1	1/2	1/1		
		Crustacea	1	3	1/1	...	1/1		
1/1		Bryozoa	4	5					
3/8		Brachiopoda	4	19	2/5				
7/14	44 genera and 153 species.	Monomyaria	11	55	7/14	3/11	4/13	2/4	
11/19		Dimyaria..................	33	98	12/27	7/7	9/17	3/3	1/1
2/2		Gasteropoda	20	28	5/6	3/3	4/4		
1/1	Cephalopoda.	Ammonites...............	1	3	1/1	1/1			
		Nautili.....................	1	1	1/1	...	1/1		
		Belemnites, Teuthidæ (none).							
		Pisces	2	2					
		Reptilia	1	1					
		Mammalia (none).							
28/48		....	92	244	30/56	15/24	21/39	5/7	1/1

§ 9. Kellaways Rock.

Plantæ.—None known.

Amorphozoa.—None known.

Cœlenterata.—None known.

Echinodermata.—Only 3 species of the genus *Astropecten* are known to occur; they are *Astropecten arenicolus*, *A. clavæformis*, and *A. orion*. No Echinoidea or Crinoidea have yet occurred.

Annelida.—*Serpula intestinalis* stands alone out of the 35 species that occur in the Oolitic rocks. This same species also occurs in the Oxford Clay and Corallian beds.

Crustacea.—*Glyphea rostrata* and *G. Stricklandi* are the only two known; the former commences in the Inferior Oolite and

appears to be the same form that also ranges into the Coral Rag. Out of 64 Jurassic species it is the only long-lived form. 33 species occur in the Lower Lias, all restricted; 12 in the Upper Lias, all equally characteristic; 5 in the Great Oolite; and 3 in the Cornbrash. The Oxford and Kimmeridge Clays only have 2 species in common, *Glyphea leptomana* and *G. Stricklandi.*

Bryozoa.—None.

Brachiopoda.—*Terebratula coarctata, T. intermedia, T. obovata, Waldheimia ornithocephala, W. umbonella, Rhynchonella varians, R. socialis, R. yaxleyensis, Lingula lævis,* and *Discina centralis* comprise all the species known in the Kellaways Rock. *R. varians* and *W. ornithocephala* occur also in the Oxford Clay, and *W. obovata* in the Corallian beds.

Lamellibranchiata. *Monomyaria.*—11 genera and 28 species occur, $\frac{7}{14}$ of which appeared in and came from the Cornbrash, $\frac{7}{16}$ pass to the Oxford Clay, and $\frac{7}{14}$ to the Corallian rocks. The species that commence in the Kellaways Rock are *Anomia inæquivalvis, Avicula ovalis, Exogyra nana, Gryphæa bilobata, G. dilatata, Lima notata, L. obscura, Ostrea archetypa, O. procerula, O. striata, O. undosa,* and *Pinna mitis*; but only 4 genera and 8 of the above species are essentially Callovian, viz. *Anomia inæquivalvis, Gryphæa bilobata, Lima notata, L. obscura, Ostrea archetypa, O. procerula, O. striata,* and *O. undosa.* The Kellaways Rock is finely developed in Yorkshire, north and south of Scarborough, in the Castle Hill and near North Cave. In Lincolnshire it has thinned away to 3 feet; and appears no more until recognized in its original area in Wiltshire, where, in the form of rock, it is richly fossiliferous, individually rather than specifically.

Dimyaria.—18 genera and 57 species form the Dimyarian fauna of the Kellaways Rock; $\frac{12}{27}$ are also Cornbrash forms, $\frac{8}{13}$ pass up to the Oxford Clay, and $\frac{7}{14}$ to the Corallian beds. The special Callovian forms are *Anatina versicostata, Cardium subdissimile, Corbis lævis, Cucullæa æmula, C. minima, Isocardia clarissima, Lucina lirata, L. pulchra, Modiola Morrisii, Myacites Alduini, Nucula ornata, Solemya Woodwardiana, Trigonia complanata, T. paucicostata, T. rupellensis,* and *T. Williamsoni.* These all commence in and are confined to the Kellaways, none ranging higher. It will be seen that 9 of these genera are only represented by 1 species. If the same occurred in living genera, we should regard them as extremely rare; and there are examples in our modern seas of the same rarity (e. g. *Pholadomya*). It is only negative evidence withal that we possess when dealing with the paucity or abundance of species in any given formation; but the tabular analysis of the fauna of all the formations (Table XLIV. p. 226) faithfully represents the present aspect and value of the work done by British palæontologists up to the present time. *Cardium* (6 species), *Myacites* (6), *Pholadomya* (7), and *Trigonia* (6 species), are the only genera fairly well represented.

Gasteropoda.—Very few of the genera and species of the Kellaways Gasteropoda range higher. The fauna, too, is small, only $\frac{10}{19}$.

The special or restricted species are *Alaria arsinoe*, *Cerithium abbreviatum*, *C. crebrum*, *Chemnitzia lineata*, *Patella graphica*, *Pleurotomaria arenosa*, *P. guttata*, and *P. striata*. None of these occur out of the Kellaways Rock; and most of them are Yorkshire species. 4 species first appear in the Kellaways and pass to higher horizons. They are *Pleurotomaria depressa*, *Alaria armigera*, *Actæon retusus*, and *Dentalium annulatum*. Thus the 8 restricted forms and these 4 which first appear, or 12 species, must be considered as constituting the typical Gasteropoda of the formation. Only 5 genera and 6 species out of the $\frac{10}{19}$ unite the Lower and Middle Oolites. They are:—*Alaria bispinosa*, *A. trifida*, *Dentalium entaloideum*, *Amberlya ornata*, *Natica punctura*, and *Pleurotomaria granulata*. $\frac{3}{4}$ pass to the Oxford Clay, and $\frac{4}{5}$ to the Corallian beds.

Cephalopoda. *Ammonites*.—No less than 41 species of Ammonites suddenly appear in the Callovian beds. 33 of these occur in the Yorkshire deposits. Our knowledge of these is largely due to the researches of Professor Phillips and the late Mr. Leckenby*. 20 of the 41 species pass to the Oxford Clay and 4 to the Corallian beds. The 17 species actually confined to the Kellaways group are *Amm. alternans*, *Amm. auritulus*, *Amm. Bakeriæ*, *Amm. Baugieri*, *Amm. convolutus*, *Amm. Eugenii*, *Amm. flexicostatus*, *Amm. fluctuosus*, *Amm. goliathus*, *Amm. Henrici*, *Amm. Lalandianus*, *Amm. Lonsdalei*, *Amm. oculatus*, *Amm. planula*, *Amm. tatricus*, *Amm. raricostatus*, and *Amm. Vernoni*. Only 1 species (*Amm. macrocephalus*) passes from the Cornbrash to the Kellaways. The 4 species that pass to the Corallian beds are *Amm. alligatus*, *Amm. Gulielmi*, *Amm. perarmatus*, and *Amm. placenta*. They range no higher. Scarborough, Redcliff, Hackness, and Gristhorpe are the chief localities from which the Kellaways Ammonites have been obtained.

Ancyloceras.—Only 2 Jurassic species of *Ancyloceras* are known—*A. annulatum*, in the Inferior Oolite, and *A. calloviense*, from the Kellaways Rock of Wiltshire.

Nautili.—*Nautilus calloviensis* and *N. hexagonus* are the only species yet known. *N. hexagonus* occurs in the Cornbrash (?), Kellaways, and Corallian beds.

Belemnitidæ.—The Dibranchiata are equally poor in species. We only know 3 species, viz. *Belemnites Owenii*, *B. hastatus*, and *B. tornatilis*.

Pisces.—Teeth of *Strophodus radiato-punctatus* occasionally occur; no other forms are known.

Reptilia.—None known.

Mammalia.—None known.

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TABLE XXXVI.—*Analysis and Distribution of the Kellaways Species.*

From Cornbrash.		Classes.	Genera.	Species.	Oxford Clay.	Coralline Oolite.	Kimmeridge Clay.	Portland Oolite.
		Plantæ. } None.						
		Amorphozoa. } None.						
		Rhizopoda. } None.						
		Cœlenterata. } None.						
		Echinodermata	1	3				
1/1		Annelida..................	1	1	1/1	1/1		
1/1		Crustacea.................	1	2	1/1	1/1	1/1	
		Bryozoa (none).						
3/5		Brachiopoda	5	10	2/2	1/1		
7/14	29 genera and 85 species.	Monomyaria	11	28	7/16	7/14	3/4	1/1
12/27		Dimyaria	18	57	8/13	7/14	4/6	
5/6		Gasteropoda	10	19	3/4	4/5		
1/1	Cephalopoda.	Ammonites..............	1	41	1/20	1/4		
		Ancyloceras	1	1	1/1			
1/1		Nautili....................	1	2				
		Belemnites	1	3	1/2			
		Teuthidæ (none).						
		Pisces	1	1				
		Reptilia (none).						
		Mammalia (none).						
31/56		....	52	168	25/60	22/40	8/11	1/1

§ 10. OXFORD CLAY.

PLANTÆ.—The Cycadeæ stand almost alone as representing the flora of the Middle Oolitic rocks. *Bucklandia, Bennettites, Yatesia,* and *Cycadeostrobus* are the only 4 genera known; together they only yield 5 species. *Cycadeostrobus sphæricus*, Carr., is the only species known in the Oxford Clay.

RHIZOPODA.—*Bolivina punctata*, a *Polymorphina*, and *Pulvinulina Kaestini* are the only Foraminifera known to occur in the Oxford

Clay. I believe there are no other known species in the Middle Jurassic strata; but 7 genera and 13 species occur in the Kimmeridge Clay.

Cœlenterata.—None known.

Echinodermata.—*Pentacrinus Fisheri*, *Amphiura Prattii*, and *Cidaris inspirata* compose the Echinodermal fauna of the Oxford Clay. The calcareous strata of the Corallian rocks above hold a numerous series ($\frac{15}{28}$). The four chief horizons are, as we should expect from the nature of the deposits, the Inferior Oolite (51), the Great Oolite (53), the Cornbrash (23), and the Corallian beds (28). The large fauna which accompanies each is largely due to physical conditions and adaptation. The above 3 species are confined to the Oxford Clay.

Annelida.—*Serpula intestinalis* and *S. vertebralis* are the only species occurring. The Corallian beds above possess 3 genera and 8 species.

Crustacea.—5 genera and 6 species known; 3 of these are unsatisfactory forms—*Estheria Murchisoniæ*, *Pollicipes planulatus*, and *P. concinnus*. The Macrura, through *Glyphea leptomana*, *G. Stricklandi*, and *Mecochirus Pearcei*, constitute the Crustacean fauna of the Oxford Clay. None pass to the Corallian rocks; but 2 species are also Kimmeridgian.

Bryozoa.—None known.

Brachiopoda.—5 genera and 10 species range through the Oxford Clay, viz. *Waldheimia bucculenta*, *W. impressa* and *W. ornithocephala*, *Terebratula insignis* and *T. oxoniensis*, *Rhynchonella lacunosa* and *R. socialis*, *Lingula Cranæ* and *L. ovalis*, and *Discina latissima* (?). The only species that range to higher beds are *Lingula ovalis* to the Kimmeridge Clay; and *Rhynchonella lacunosa*, *Waldheimia bucculenta*, and *Terebratula insignis* to the Corallian beds.

Lamellibranchiata. *Monomyaria*.—With the 7 genera and 16 species which appeared in the Kellaways, the Oxford Clay yields 9 genera and 26 species, only 7 of which are restricted; these are *Pecten lævis*, *Ostrea hebridica*, *O. inæqualis*, *Lima argillacea*, *Gryphæa elongata*, *Avicula pterosphænia*, and *Anomia estuarina*. 13 species pass to the Corallian rocks and 6 to the Kimmeridge Clay. The species common to the Oxford and Kimmeridge Clay are *Avicula dorsettensis*, *Av. inæqualis*, *Gervillia aviculoides*, *Pecten arenatus*, *P. demissus*, and *P. vimineus*. *Pecten* is the only genus in which the species number more than 4.

Dimyaria.—21 genera and 48 species constitute the whole fauna of this group of the Bivalvia; 8 genera and 13 species ally the Oxford and Kellaways Dimyaria; 26 of the 48 species exclusively belong to the Oxford Clay. None of the genera are largely represented; 10 genera contain only 1 species each. *Cyrena*, through the estuarine "Staffin shales," occurs for the first time in the Jurassic series, and with 6 species. In the Wealden this is the most prominent genus amongst the Lamellibranchiata, no less than 8 species being known in the Weald Clay. *Trigonia* is the

only genus out of the 21 that is represented by so many as 5 species. The Oxford Clay and Corallian beds are allied through 9 genera and 14 species, and 3 species range into the Kimmeridge Clay, viz. *Trigonia clavellata*, *Modiola bipartita*, and *Cardium striatulum*. There is an estuarine element in this horizon, shown by a certain facies in the Mollusca, and the genera possessing this character are the most numerously represented—*Corbula* 3 species, *Cyrena* 6, *Potamomya* 3, *Unio* 1. This is more evident in the Dimyarian than the Monomyarian genera; it is equally manifest in the Gasteropoda, *Cerithium*, *Hydrobia*, *Littorina*, *Neritina*, *Melania*, and *Valvata* being suggestive of estuarine conditions. In Scotland, at Loch Staffin (Isle of Skye) an estuarine condition was long ago determined by Prof. Forbes *. In his paper Forbes speaks of the Staffin area as follows:—"The succession of events indicated by the section I have described is of no small interest, when considered in its bearing on the physical geography of our area during the Oolitic epochs. ...... But at the termination of the deposition of the middle oolitic strata, we have indications of most important changes, and of the conversion of the bed of the Hebridean oolitic sea into an estuarine and terrestrial area, which after a considerable lapse of time became submerged under oceanic conditions and had a new series of marine strata deposited upon it" (*loc. cit.* p. 108).

Gasteropoda.—Only 10 genera and 17 species occur, of which 9 species are confined to the Oxford Clay; and 3 genera and 4 species unite the Kellaways below with this horizon. The purely Oxford-Oolite species are *Cerithium Damonis*, *Leptoxis trochiformis*, *Littorina Meriani*, *Melania inermis*, *Neritina arata*, *Paludina scotica*, *Pleurotomaria amphicœlia*, *P. Münsteri*, and *Valvata præcursor*. These restricted forms, as in almost every case through the Jurassic deposits, occur only in single species. *Pleurotomaria reticulata* is the only species of Gasteropod out of the 17 that passes from the Oxford Clay to the Corallian beds. Thus the Oxford Clay Gasteropoda are of specific value; but, as in the great argillaceous groups from the Lias up to and including the Kimmeridge Clay, the mass of the species belong to the Lamellibranchiata. The extreme poverty of species is shown by the following figures for the 10 genera:—

Alaria, Littorina, Pleurotomaria, each possess	3	species	=9
Neritina possesses	2	,,	=2
Cerithium, Leptoxis, Hydrobia, Melania, Paludina, and Valvata each possess	1	,,	=6
			17

Cephalopoda. *Ammonites*.—No less than 45 species of Ammonites occur in the Oxford Clay, 11 of which pass to the succeeding Coralline Oolite and 4 to the Kimmeridge Clay; 20 species ranged from the Kellaways Rock below. The special Ammonite fauna is 18

* Quart. Journ. Geol. Soc. vol. vii. pp. 104–113.

species; they are so important stratigraphically that I name them —*A. alternans*, *A. auritulus*, *A. Bakeriæ*, *A. Baugieri*, *A. Comptoni*, *A. convolutus*, *A. Eugenii*, *A. flexicostatus*, *A. fluctuosus*, *A. goliathus*, *A. Henrici*, *A. Lalandianus*, *A. Lonsdalei*, *A. oculatus*, *A. planula*, *A. tatricus*, *A. raricostatus*, *A. Vernoni*. These 18 species are entirely confined to the Oxford Clay. The 4 species that pass to the Kimmeridge Clay are *A. longispinus*, *A. Lamberti*, *A. annularis*, and *A. anceps*. Very few species occur in the Oxford Clay of Yorkshire; they mostly occur in Wiltshire, Huntingdonshire, Lincolnshire, Oxfordshire, and Western Scotland. The groups represented in the Oxford Clay are the *Dentati*, *Flexuosi*, and *Ornati* (species of *Cosmoceras*), the *Armati* (*Aspidoceras longispinum* and *perarmatum*), the *Amalthei* through *A. cordatus*, *A. Lamberti*, and the *Macrocephali* through *Stephanoceras macrocephalum*. Twenty Oxford-Clay species occur in the Western Isles (Scotland), in which the groups *Dentati*, *Ornati*, and *Flexuosi* are conspicuous, species of the genera *Cosmoceras* and *Aspidoceras* prevailing*.

Ancyloceras.—*Ancyloceras calloviense* is the only form occurring, though sparingly. It is chiefly Callovian.

Nautili.—None known.

Belemnites.—13 species have been described, but probably only 10 occur, and 3 varieties of the species *B. Owenii*. Since the Inferior Oolite, which yielded 16 species, there has been no such illustration of the genus. The Fuller's Earth has only 3 species, the Great Oolite 3, Forest Marble none, Cornbrash none, Kellaways Rock 3, and the Oxford Clay under notice 13. They decline again in the two next horizons. The Corallian beds possess only 4, the Kimmeridge Clay 8, and the Portland beds none. The varieties of *B. Owenii* are *B. Puzosianus*, *B. verrucosus*, and *B. tornatilis*. Admitting these to be varieties of that species, the number may be reduced to 10. Only 1 species (*B. abbreviatus*) passes to the Corallian series and Kimmeridge Clay; *B. excentricus* may be only a var. of *B. abbreviatus*. Only 6 of the 13 species are confined to the Oxford Clay, viz. *B. Beaumontianus*, *B. excentricus*, *B. obeliscus*, *B. spicularis*, *B. strigosus*, and *B. sulcatus*. These 13 forms, with the one exception, are all Middle Oolitic, none appearing below the Kellaways Rock or above the Corallian beds. 3 species pass to the Corallian rocks, viz. *B. abbreviatus* and var. *excentricus*, and *B. hastatus*. *B. abbreviatus* also ranges to the Kimmeridge Clay or the Upper Oolite. *B. hastatus* and *B. Owenii* are the only two species that come up from the Kellaways below.

Teuthidæ.—*Acanthoteuthis antiquus* and *Geoteuthis brevispinus* illustrate this family; they are associated with the great series of

* To enter into the distribution of the Middle Oolite Ammonites according to their groups and new genera would alone constitute an entire address; the difficulty is to reduce any history of this group to moderate limits. D'Orbigny in this division of the Jurassic rocks (Oxfordian) enumerates no less than 43 species of Ammonites, 12 Belemnites, and 4 *Nautili*.

Ammonites collected from the Oxford Clay of Christian Malford. *Acanthoteuthis* is the *Belemnoteuthis* of Pearce, the *Lipoteuthis* of Meyer, and the *Enoploteuthis* of D'Orbigny. Mantell and Owen have made this genus classical through their papers in the Philosophical Transactions of the Royal Society. Besides *Coccoteuthis latipinnis*, from the Kimmeridge Clay, we have an undescribed form of the same genus from the Oxford Clay of Chippenham. In many of the older collections, made at the time of the construction of the Great Western Railway, new species, I doubt not, will yet be found on careful examination.

Pisces.—*Aspidorhynchus euodus*, *Lepidotus macrorhynchus*, *Leptolepis costalis*, and *L. macrophthalmus* are all the known fishes in the Oxford Clay, neither do they occur out of it. All the species of fish occurring in the Lias, the Lower Oolite, Middle Oolite, and Upper Oolite are totally distinct; no species unites any of the divisions, so that the range of the 61 genera and 219 species occurring in the Jurassic rocks is definite, and of great significance stratigraphically. Only 2 species out of 106 are common to the Lower and Middle Lias, and only 2 to the Lower and Upper Lias, and none pass to any horizon in the Oolitic beds above. No Lower-Oolite species pass to the Middle Oolite, and no Middle-Oolite species to the Upper. The Great Oolite has $\frac{20}{58}$, none ranging higher; after which the Kimmeridge Clay yields 15 species, the only large number.

Reptilia.—13 species representing 7 genera have now been described from the Oxford Clay, namely—*Ichthyosaurus dilatatus*, *I. thyreospondylus*, *Megalosaurus Bucklandi*, *Murænosaurus Leedsii*, *Plesiosaurus eurymerus*, *P. Leedsii*, *P. oxoniensis*, *P. plicatus*, *P. trochanterius*, *Pliosaurus æqualis*, *P. Evansi*, *Streptospondylus Cuvieri*, and *Priodontognathus Phillipsii*; and only two of these pass to the Corallian beds (*Pliosaurus æqualis* and *Megalosaurus Bucklandi*), and 5 species to the Kimmeridge Clay. 6 species are specially Oxfordian, viz. *Murænosaurus Leedsii*, *Plesiosaurus eurymerus*, *P. Leedsii*, *P. oxoniensis*, *Pliosaurus Evansi*, and *Priodontognathus Phillipsii*. The above genera illustrate the following 4 orders—the Opisthocœlian Crocodilia through *Streptospondylus*, the Sauropterygia through *Murænosaurus*, *Pliosaurus*, and *Plesiosaurus*, the Ichthyopterygia through *Ichthyosaurus*, and the Dinosauria through *Megalosaurus* and *Pristodontognathus*.

Mammalia.—None known.

[For the Analysis of the Oxford-Clay species see Table XXXVII., p. 214.]

Table XXXVII.—*Analysis and Distribution of the Oxford-Clay Species.*

From Kellaways Rock.		Classes.	Genera.	Species.	Corallian beds.	Kimmeridge Clay.	Portland Oolite.
		Plantæ	1	1			
		Amorphozoa.					
		Rhizopoda	3	3	...	$\frac{2}{2}$	
		Cœlenterata (none).					
		Echinodermata	3	3			
$\frac{1}{1}$		Annelida	1	2	$\frac{1}{1}$		
$\frac{1}{1}$		Crustacea	5	6	...	$\frac{2}{2}$	
		Bryozoa (none).					
$\frac{2}{3}$		Brachiopoda	5	10	$\frac{3}{3}$	$\frac{1}{1}$	
$\frac{7}{16}$	30 genera and 74 species.	Monomyaria	9	26	$\frac{9}{13}$	$\frac{3}{6}$	
$\frac{8}{13}$		Dimyaria	21	48	$\frac{9}{14}$	$\frac{3}{3}$	
$\frac{3}{4}$		Gasteropoda	10	17	$\frac{1}{1}$		
$\frac{1}{20}$		Ammonites	1	45	$\frac{1}{11}$	$\frac{1}{4}$	
		Ancyloceras	1	1	...	$\frac{1}{1}$	
	Cephalopoda.	Nautili (none).					
$\frac{1}{2}$		Belemnites	1	13	$\frac{1}{3}$	$\frac{1}{1}$	
		Teuthidæ	2	2			
		Pisces	3	4			
		Reptilia	7	13	$\frac{2}{2}$	$\frac{3}{5}$	
		Mammalia (none).					
$\frac{24}{59}$		....	73	194	$\frac{27}{48}$	$\frac{17}{25}$	

§ 11. Corallian Rocks.

Plantæ.—4 genera and 7 species occur, all confined to these rocks. It is necessary that I name them, as, with the exception of 2 species, they are the last we know of the Jurassic flora. The Coniferæ and the Cycadeæ are the two families represented. *Araucarites Hudlestoni* is the only Conifer ; *Bennettites Peachianus*, *Bucklandia Milleriana*, *Yatesia crassa*, and *Y. Joassiana* represent the Cycadeæ. *Carpolithes Bucklandi* and *C. conicus* must be doubt-

fully referred; the last-named species is said to have occurred in the Great Oolite; this is also doubtful.

Amorphozoa.—*Scyphia cylindrica* and *Spongia floriceps* are all that are known out of the 11 occurring in the Jurassic rocks; only one species occurs in the Lower Lias (*Grantia antiqua*), 9 in the Great Oolite, and the 2 Corallian species now recorded.

Rhizopoda.—No species is known to occur in the Lower Oolite, and only 3 in the Middle; *Dentalina* may be the single genus in the Corallian beds.

Cœlenterata.—Nearly all the Actinozoa of the Corallian rocks are compound or branching forms, the exceptions being *Montlivaltia dispar* and *Protoseris Waltoni.* 10 genera and 14 species range through the beds composing this formation; the remaining 8 genera and 12 species are—*Comoseris irradians, Goniocera socialis, Isastræa explanata, I. Greenoughii, Rhabdophyllia Phillipsii, R. Edwardsii, Stylina de la Bechei, S. tubulifera, Thamnastræa arachnoides, T. rotata, Thecosmilia annularis,* and *Calamophyllia Stokesii.* All are confined to the Coral Rag, except one species, viz. *Thamnastræa arachnoides*, which is also Cornbrash. Dorset and Wilts, with Malton, Ayton, Hackness, and Seamer, in Yorkshire, are the chief localities known. This special Coral fauna is the largest since the deposition of the Great Oolite, which yields $\frac{15}{38}$ species, and the Inferior Oolite $\frac{19}{48}$. We have seen that only one species occurs in the Forest Marble and 1 in the Cornbrash. No species is known either in the Kellaways Rock or the Oxford Clay; nor do we know any species in the Kimmeridge Clay.

Echinodermata.—15 genera and 28 species occur, and of these 26 are entirely confined to the Corallian beds. Two species, *Echinobrissus dimidiatus* and *E. orbicularis*, are also Cornbrash. *Millericrinus echinatus* is the only Crinoid, and *Astropecten rectus* the only Asteroid. The group Echinoidea Endocyclica is represented by 6 genera and 11 species, and the Exocyclica by 7 genera and 15 species; they are:—

Endocyclica.	Cidaris	2 species.	*Exocyclica.*	Clypeus	1 species.
	Glypticus	1 ”		Collyrites	1 ”
	Hemicidaris	1 ”		Echinobrissus	5 ”
	Hemipedina	2 ”		Holectypus	1 ”
	Pseudodiadema	4 ”		Hyboclypus	1 ”
	Stomechinus	1 ”		Pygaster	1 ”
				Pygurus	5 ”
		11			15

Compared with the Inferior and Great Oolite the Echinodermal fauna is small; the former yields $\frac{22}{51}$ species, and the latter $\frac{22}{53}$.

Annelida.—*Serpula* with 5 species, and *Vermicularia* with 2; or 2 genera and 7 species comprise all the known Corallian Annelida; and, except the Inferior Oolite, with 11 species, no other horizon in the Jurassic rocks has yielded so many forms.

Crustacea.—*Glyphea ferruginea* and *G. rostrata* are the only 2 species known; the latter ranges from the Inferior Oolite. The Oxford Clay below holds 6 species, and the Kimmeridge above 7. *Glyphea ferruginea* is the only species confined to the Corallian rocks.

Bryozoa.—Two doubtful species, *Heteropora conifera* and *Terebellaria ramosissima* occur, but they are also found in the Inferior and Great Oolite.

Brachiopoda.—21 species occur in the Corallian beds, representing 7 genera—*Terebratula* 7 species, *Waldheimia* 6, *Rhynchonella* 3, *Lingula*, *Discina*, and *Zelania* one each, and *Thecidium* 2. *Discina Humphresiana* ranges into the Kimmeridge Clay, and is the only species connecting the two horizons.

Lamellibranchiata. *Monomyaria*.—14 genera and 58 species are known to occur; of these 16 are Corallian forms only. 7 genera and 15 species pass to the Kimmeridge Clay, 9 genera and 13 species unite the Oxford Clay below with the Corallian. The genera most largely represented are *Avicula* with 7 species, *Lima* 8, *Pecten* 5, and *Ostrea* 9. *Plicatula*, *Pteroperna*, *Trichites*, and *Gervillia* each possess but one species. *Perna*, *Pinna*, *Hinnites*, and *Placunopsis* have 2 species each. We should expect to find these genera more largely represented on comparing them numerically with the Inferior Oolite, in which the four first-named genera yield 17 species, and the four last 17 species. The Monomyarian fauna in the Inferior Oolite is $\frac{15}{106}$ species, in the Great Oolite $\frac{16}{80}$, the Cornbrash $\frac{11}{55}$, and the Corallian under examination $\frac{14}{58}$. The conditions of deposition and accumulation are most nearly allied to those of the Great Oolite. Space will not allow me to name the species constituting the fauna of this horizon; my only resource is to treat them numerically. *Exogyra nana*, *E. spiralis*, *Lima rustica*, *Ostrea solitaria*, and *Perna mytiloides* range to the Portland beds.

Dimyaria.—29 genera and 93 species occur in this group of the Bivalvia; no less than 47 of the 93 species are peculiar to it, and they belong to 22 of the 29 genera. 9 genera and 14 species occur in the Oxford Clay below, and 10 genera and 12 species pass to the Kimmeridge Clay; but *Thracia depressa* and *Modiola pallida* are the only 2 species that pass to the Portland beds. *Astarte*, *Arca*, *Modiola*, *Lucina*, *Pholadomya*, and *Trigonia* are the genera most largely represented. United their species number 46, or 50 per cent. of the whole. 10 genera possess only 1 species each; this tends to show the importance of correctly determining the genera in an extensive fauna, so that undue value may not be assigned to those having only a single species. In the present, as in many other formations, nearly one half are thus poorly represented. In the present instance we have little doubt of correct determination; such genera as *Gastrochæna*, *Homomya*, *Myoconcha*, *Mytilus*, *Pholas*, *Tancredia*, and *Protocardium* can hardly be mistaken; it is the *single representative* that causes anxiety when examining extensive catalogues of species or specimens in collections.

Gasteropoda.—With the exception of 7 species, the whole of the 67 known species are confined to the Corallian rocks. *Pleurotomaria reticulata* passes to the Kimmeridge Clay. The only species uniting the Oxford Clay and Coral Rag is *Littorina muricata*; but 5 of the Kellaways species bridge over the Oxford Clay and reappear in the Corallian; they are *Pleurotomaria granulata*, *Dentalium annulatum*, *D. entaloideum*, *Alaria bispinosa*, and *Actæon retusus*. No species passes to the Portland Oolite. Probably in no other horizon in the British rocks are the Gasteropoda so distinctive of the beds they occupy; for we have seen that out of the 67 species known 60 *are peculiar to or characteristic* of the Corallian beds.

Cephalopoda. *Ammonites.*—21 species occur, 9 of which are essentially Corallian; they are *A. anceps-albus*, *A. Babeanus*, *A. cadonensis*, *A. rupellensis*, *A. plicatilis*, *A. pseudo-cordatus*, *A. retroflexus*, *A. Sutherlandiæ* (*goliathus*), and *A. Williamsoni*. 11 of the 21 species also occur in the Oxford Clay, and 2 pass up to the Kimmeridge Clay (*A. achilles* and *A. longispinus*). Only one species, *A. macrocephalus*, connects the Lower and Middle Oolitic rocks; the only 5 *Ammonites* that occur in or range all through three of the Middle Oolite divisions are *A. alligatus*, *A. Duncani*, *A. Gulielmi*, *A. perarmatus*, and *A. placenta*; and only 5 connect the Middle and Upper Oolites, in which latter there are 31 species; these last are *A. achilles*, *A. anceps*, *A. annularis*, *A. Lamberti*, and *A. longispinus*, and they do not pass above the Kimmeridge Clay. Every care has been taken with reference to the details and analysis of the above species.

Nautili.—*Nautilus hexagonus* is the only species in the Corallian beds; it had previously occurred in the Cornbrash and Kellaways Rock.

Belemnites.—*B. abbreviatus* with its two varieties, *B. oxyrhynchus* and *B. excentricus*, and *B. hastatus* constitute all the known Dibranchiata. *B. abbreviatus* also appears in the Kimmeridge Clay above.

Pisces.—*Gyrodus Cuvieri*, *G. punctatus*, and *Hybodus obtusus* are all that have occurred of this class.

Reptilia.—*Chelys Blakii*, *Megalosaurus Bucklandi*, and *Pliosaurus* are the only representatives, and these illustrate three orders —the *Chelonia*, *Dinosauria*, and *Enaliosauria* or *Sauropterygia*. *Megalosaurus* and *Pliosaurus* also occur in the Oxford Clay.

Mammalia.—None known.

[For the Analysis of the Corallian species see Table XXXVIII., p. 218.]

Table XXXVIII.—*Analysis and Distribution of the Corallian Species.*

From Oxford Clay.		Classes.	Genera.	Species.	Kimmeridge Clay.	Portland Oolite.
		Plantæ	4	7		
		Amorphozoa	2	2		
		Rhizopoda	1	1		
		Cœlenterata	10	14		
		Echinodermata	15	28		
$\frac{1}{1}$		Annelida	2	7		
		Crustacea	1	2		
		Bryozoa	2	2		
$\frac{3}{3}$		Brachiopoda	7	21	$\frac{1}{1}$	
$\frac{9}{13}$	43 genera and 151 species.	Monomyaria	14	58	$\frac{7}{15}$	$\frac{4}{5}$
$\frac{9}{14}$		Dimyaria	29	93	$\frac{10}{12}$	$\frac{2}{2}$
$\frac{1}{1}$		Gasteropoda	21	67	$\frac{1}{1}$	
$\frac{1}{11}$	Cephalopoda.	Ammonites	1	21	$\frac{1}{2}$	
		Nautili	1	1		
$\frac{1}{3}$		Belemnites	1	4	$\frac{1}{1}$	
		Teuthidæ (none).				
		Pisces	2	3		
$\frac{2}{2}$		Reptilia	3	3	$\frac{1}{1}$	
		Mammalia (none).				
$\frac{27}{48}$		....	116	334	$\frac{22}{33}$	$\frac{6}{7}$

§ 12. Kimmeridge Clay.

Plantæ.—*Pinites depressus* is the only known plant in the Kimmeridge Clay. This constitutes the entire known flora of the Upper Oolitic rocks in Britain.

Amorphozoa.—None known.

Rhizopoda.—7 genera and 13 species of Foraminifera occur in the Kimmeridge Clay; they are *Bolivina* 1 species, *Dentalina* 3, *Glandulina* 1, *Lagena* 2, *Planularia* 1, *Polymorphina* 3, and *Pulvinulina* 2 species. From the Upper Lias to the Kellaways Rock inclusive there is scarcely any evidence of Foraminifera in the

British Jurassic rocks. I do not doubt their occurrence, but they have not been recorded.

Cœlenterata.—As in the Kellaways and Oxford Clay, or Oxfordian strata, so in the Kimmeridge, no remains whatever of Actinozoa have occurred notwithstanding all the research into these three horizons.

Echinodermata.—*Cidaris baculifera*, *C. boloniensis*, *C. spinosus*, *Hemipedina Cunningtoni*, *H. corallina*, *H. Morrisii*, and *Pentacrinus sigmaringensis*, or 3 genera and 7 species, compose the Echinodermal fauna of the Kimmeridge Clay.

Annelida.—Only 3 species known, *Serpula Royeri*, *S. variabilis*, and *Vermicularia contorta*.

Crustacea.—*Callianassa isochela*, *Eryma Babeaui*, *Glyphea leptomana*, *G. Stricklandi*, *Mecochirus Peytoni*, *Pollicipes Hausmanni*, and *Scalpellum reticulatum* all occur. The species of *Glyphea* are also in the Oxford Clay.

Bryozoa.—None known.

Brachiopoda.—Four species of *Rhynchonella*, 3 *Discinæ*, 1 *Lingula*, and 2 species of *Terebratula*, or 4 genera and 10 species, are all that are known in the Kimmeridge Clay. Individuals of the non-articulate forms *Lingula* and *Discina* are abundant. *Discina Humphresiana* and *Lingula ovalis* also occur in the Corallian series. The 4 *Rhynchonellæ* are *R. Sutherlandi*, *R. subvariabilis*, *R. inconstans*, and *R. pinguis*. The remainder are *Terebratula Gesneri* and *T. Joassi*.

Lamellibranchiata. *Monomyaria*.—11 genera and 42 described species are known in the Kimmeridge Clay. Prof. Blake's researches have added many new forms to the fauna of the British rocks, both in this group and the Dimyaria. No less than 23 species in this group are confined to the Kimmeridge beds. 6 pass to the Portland; they are *Exogyra nana*, *E. spiralis*, *Ostrea deltoidea* ?, *O. expansa*, *O. solitaria*, and *Perna mytiloides*. The alliance below with the Corallian rocks is through 15 species, belonging to 7 genera. 2 genera, *Ostrea* with 12 species, and *Pecten* with 10, are largely represented; the remaining 9, except *Avicula* with 5 species, do not average two to each genus.

Dimyaria.—26 genera and 58 species of this group occur in the Kimmeridge Clay. 36 of these 58 species are confined to this horizon. 12 species are common to it and the Corallian beds below; these passage or uniting species are *Astarte ovata*, *Cardium striatulum*, *Goniomya minuta*, *G. v-scripta*, *Homomya gracilis*, *Modiola bipartita*, *M. pallida*, *Myacites oblatus*, *Opis corallina*, *Pholadomya paucicosta*, *Thracia depressa*, and *Trigonia clavellata*; probably *Mactra tenuissima* is also a passage form. So far as we know, 7 genera and 10 species pass to the Portland beds. I deem it necessary to name the connecting species of the Kimmeridgian and Portlandian rocks; they are *Cardium morinicum*, *Modiola pallida*, *Nucula obliquata*, *Pholadomya rustica*, *Pleuromya æquistriata*, *Thracia depressa*, *Trigonia incurva*, *T. Manseli*, *T. muricata*, and *T. Pellati*.

Gasteropoda.—The distinctiveness of the Gasteropod fauna in the Corallian beds is equally complete and definite; in the Kimmeridgian 23 species occur, and with two exceptions, *Pleurotomaria reticulata* and *Turritella minuta*, all are restricted. *Pleurotomaria reticulata* occurs in the Corallian beds, and the *Turritella* passes to the Portland. This concise history of the Kimmeridge Gasteropoda, like that of the Corallian, has scarcely any parallel in any other member of the British strata. 8 of the 12 genera that occur have only one species in each; they are *Alaria*, *Chemnitzia*, *Dentalium*, *Neritopsis*, *Pleurotomaria*, *Pseudomelania*, *Rissoina*, and *Turritella*. *Cerithium*, the only genus at all largely represented, includes 6 species, and *Natica* has 4.

Many of the genera with only one known species each in the Kimmeridge Clay are extremely rich in species in their range through the Jurassic rocks. Thus *Alaria* possesses 39 species, but *A. rasanensis* is the only Kimmeridgian form; *Chemnitzia* 58 species—*C. inflata* is known only; *Neritopsis*, 14 known, but *N. delphinula* is its only representative here; *Pleurotomaria* numbers no less than 110 species, 53 of which occur in the Inferior Oolite, 16 in the Great Oolite, and 38 in the Lias, but *P. reticulata* is the only known Kimmeridgian form; *Rissoina* 11, chiefly Great Oolite—*R. mossensis* is the only one here; and *Turritella* numbers 17 species, 11 of them Lias, but only *T. minuta* and *T. concava* occur in the Upper Oolite, and the latter is a Portlandian species. Thus 6 of the above 8 genera so largely represented through the Jurassic rocks (and known in the Kimmeridge beds) with *Dentalium* and *Pseudomelania*, as before stated, *exhibit only one species*. I commend those genera, both of the Lamellibranchiata and the Gasteropoda, which have only one or two species in each, to the special attention of those studying the Jurassic rocks; they offer promising material for future research.

Cephalopoda. *Ammonites*.—31 species occur in, and 22 of these are strictly confined to, the Kimmeridgian strata. Of the remaining 9 species only 4 pass to the Portlandian beds; they are *Am. triplicatus*, *Am. triplex*, *Am. biplex*, and *Am. hector*. 6 species oscillate between the Oxford Clay, Corallian, and Kimmeridgian horizons. The importance of the Ammonites, stratigraphically as well as zoologically, induces me to name those species that are essentially of this age; and as only 7 of the 11 Portlandian species are confined to that horizon, and all the Jurassic forms become extinct with the close of the Portland, this may be of importance. The 22 Kimmeridge species are *Am. accipitris*, *Am. autissiodorensis*, *Am. Benyeri*, *Am. Beaugrandi*, *Am. calisto*, *Am. cœcilia*, *Am. cymodoce*, *Am. decipiens*, *Am. eudoxus*, *Am. eumelus*, *Am. eupalus*, *Am. flexuosus*, *Am. Kapffi*, *Am. Lallerianus*, *Am. mutabilis*, *Am. orthocera*, *Am. polyplocus*, *Am. pseudo-mutabilis*, *Am. rotundus*, *Am. superstes*, *Am. Thurmanni*, and *Am. yo*. The genera *Perisphinctes*, *Aspidoceras*, *Cosmoceras*, &c. are represented amongst this series of Ammonites.

Nautili.—None known.

Belemnites.—8 species occur, and 7 of them are peculiar.

Belemnites abbreviatus is the one species which allies the Kimmeridge fauna with the Corallian and Oxfordian below. The Jurassic Dibranchiata die out with the close of the Kimmeridge. These last Jurassic Decapoda are *Bel. contortus*, *Bel. excentricus*, *Bel. explanatus*, *Bel. lateralis*, *Bel. nitidus*, *Bel. Souichii*, and *Bel. Troslyanus*. No species is known in the Portland beds of Britain or France.

Teuthidæ.—*Coccoteuthis latipinnis*, Owen. This genus, combining some of the characters of the *Sepia* with those of *Loligo*, *Sepioteuthis*, &c., is extremely rare, and is only known in the Upper Kimmeridge beds. This family being rarely preserved in the Jurassic rocks, I have kept separate: only 4 genera and 5 species are known throughout the whole of the Jurassic period; they are *Geoteuthis bollensis*, from the Lower Lias, *Beloteuthis Leckenbyi* and *B. subcostatus*, Upper Lias, *Acanthoteuthis antiquus*, Oxford Clay, and the above *Coccoteuthis latipinnis*, Kimmeridge. It is probable that in old collections and amongst the numerous remains of the Dibranchiata from the Oxford Clay of Christian Malford and Chippenham other species may be found; individually they occur in large numbers.

Pisces.—Every species in the Kimmeridge Clay is confined to it. There are 11 genera and 14 species. These 11 genera represent no less than 5 families; the Sauroidei, through *Ditaxiodus* and *Thlattodus*; the Cestraciontidæ, through *Asteracanthus* and *Strophodus*; the Pycnodontidæ, through *Gyrodus*, *Gyronchus*, *Pycnodus*, and *Sphærodus*; the Placoidei, through *Hybodus* and *Sphenonchus*; and the Cœlacanthini, through *Macropoma*.

Reptilia.—The largest number of Reptilia, either in genera or species, known in the Secondary rocks of Britain occur in the Kimmeridge Clay. Six orders are represented, viz. the Chelonia, Crocodilia, Ichthyopterygia, Sauropterygia, Pterosauria, and Dinosauria; these 6 orders contain 17 genera and 45 species.

		Species.
Crocodilia	Bothriospondylus	1
	Dakosaurus	3
	Steneosaurus	5
	Teleosaurus	2
Chelonia	Enaliochelys	1
	Pelobatochelys	1
Ichthyopterygia	Ichthyosaurus	6
	Ophthalmosaurus	1
Sauropterygia	Plesiosaurus	12
	Pliosaurus	5
Pterosauria (Ornithosauria, *Seeley*)	Pterodactylus	2
Dinosauria	Ceteosaurus	1
	Cryptosaurus	1
	Gigantosaurus	1
	Iguanodon	1
	Megalosaurus	1
	Omosaurus	1
		45

Of the above 45 species only 5 also occur in other horizons, or 40 are confined to the Kimmeridge beds. The 5 are *Ichthyosaurus dilatatus*, *I. thyreospondylus*, *Megalosaurus Bucklandi*, *Plesiosaurus plicatus*, and *P. trochanterius*, all also occurring in the Oxford Clay, the only species in the intermediate Corallian being *Megalosaurus Bucklandi*; and this is the only genus of Reptilia uniting the Kimmeridge and Portland beds. The Reptilian fauna of the Portlandian stage is 5 genera and 6 species. This large Reptilian fauna of the Kimmeridge Clay suggests a numerical analysis of the class from the Lias to the Portland inclusive, to show the variability of distribution both of the aquatic and terrestrial genera.

Table XXXIX.

Orders.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian.	Kimmeridge Clay.	Portlandian.	Total Genera and Species.
Chelonia	...	...	...	...	...	2 2	...	...	...	...	1 1	2 2	...	5 6
Crocodilia	...	...	2 4	...	...	2 5	2 2	...	...	1 1	...	4 11	1 1	12 24
Ichthyopterygia ...	1 8	1 4	1 3	...	...	1 2	...	...	...	1 2	...	2 7	...	7 26
Sauropterygia	1 18	1 1	1 9	...	...	1 1	...	...	...	3 8	1 1	2 17	2 3	12 58
Pterosauria	2 2	...	...	...	...	2 6	...	...	...	...	...	1 2	...	5 10
Lacertilia	...	...	...	...	...	1 1	...	...	...	...	...	...	...	1 1
Dinosauria	1 1	...	...	1 1	...	3 9	1 1	1 1	...	2 2	1 1	6 6	2 2	18 22

The above Table (XXXIX.) shows the genera and species in the 7 orders of Reptilia and their range through the 13 divisions of the Jurassic rocks, also the total numbers of genera and species in each of the horizons, ranging from the Lower Lias to the Portland.

Mammalia.—None known.

TABLE XL.—*Analysis and Distribution of the Kimmeridge Clay Species.*

From Corallian Rocks.	Classes.		Genera.	Species.	Portland Oolite.
		Plantæ	1	1	
		Amorphozoa (none).			
		Rhizopoda	7	13	
		Cœlenterata (none).			
		Echinodermata	3	7	
		Annelida	2	3	$\frac{1}{1}$
		Crustacea	6	7	
		Bryozoa (none).			
$\frac{1}{1}$		Brachiopoda	4	10	
$\frac{7}{15}$	37 genera and 100 species.	Monomyaria	11	42	$\frac{3}{6}$
$\frac{10}{12}$		Dimyaria	26	58	$\frac{7}{10}$
$\frac{1}{1}$		Gasteropoda	12	23	$\frac{1}{1}$
$\frac{1}{2}$	Cephalopoda.	Ammonites	1	31	$\frac{1}{4}$
		Nautili (none).			
$\frac{1}{1}$		Belemnites	1	8	
		Teuthidæ	1	1	
		Pisces	11	14	
$\frac{1}{1}$		Reptilia	17	45	
		Mammalia (none).			
$\frac{22}{33}$			103	263	$\frac{13}{22}$

§ 13. PORTLANDIAN.

PLANTÆ.—None known beyond fragments of wood.

AMORPHOZOA.—None known.

CŒLENTERATA.—*Isastræa oblonga* is the only Portland species; it is also the only coral in the Calcareous rocks of Britain whose skeleton is now entirely siliceous.

ECHINODERMATA.—*Echinobrissus Brodiei*, *Hemicidaris brillensis*,

and *H. Davidsoni* are the only 3 species known in the Portlandian beds.

ANNELIDA.—*Serpula* is the only genus known, and is represented by 4 species—*S. gordialis*, *S. quinquangularis*, *S. triserrata*, and *S. variabilis*. The first-named 3 species are Portland only. *S. variabilis* is also Kimmeridgian.

CRUSTACEA.—The Entomostraca only are represented, and these by *Cythereis interrupta* and *C. Lonsdaleiana*.

BRYOZOA.—None known.

BRACHIOPODA.—Three species of three genera, namely *Waldheimia boloniensis*, *Terebratula rex*, and *Rhynchonella*, sp.

The accompanying Table (XLI.) exhibits the numerical value and distribution of the whole of the Jurassic Brachiopoda and the total number of appearances of the species in each genus.

TABLE XLI.—*The Numerical Distribution of the Jurassic Brachiopoda.*

Genera.	Number of species in the Jurassic rocks.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Coral Rag.	Kimmeridge Clay.	Portland.	Total appearances.
1. Terebratula ...	67	4	10	3	31	5	7	4	5	3	2	7	2	1	84
2. Waldheimia ...	44	3	13	3	13	4	4	3	8	2	3	6	...	1	63
3. Terebratulina...	4	...	1	1	2	...	1	...	...	...	...	...	...	...	5
4. Thecidium	15	5	4	4	9	1	1	...	...	...	...	2	...	...	26
5. Zelania	6	1	...	1	3	...	1	...	...	...	...	1	...	...	7
6. Terebratella ...	5	...	1	...	...	...	4	...	...	...	...	...	...	...	5
7. Suessia	1	...	1	...	...	...	...	...	...	...	...	...	...	...	1
8. Spiriferina	18	5	12	5	3	...	...	...	...	...	...	...	...	...	25
9. Rhynchonella...	64	9	19	10	23	4	5	3	5	3	2	3	4	1	91
10. Lingula	12	2	3	4	1	...	...	...	...	1	2	1	1	...	15
11. Megerlia	2	...	2	...	...	...	...	...	...	...	...	...	...	...	2
12. Leptæna	6	...	3	6	...	...	...	...	...	...	...	...	...	...	9
13. Kingena	1	...	1	...	...	...	...	...	...	...	...	...	...	...	1
14. Discina	18	3	2	8	3	...	...	...	1	1	1	1	3	...	23
15. Argiope	4	3	...	...	...	...	1	...	...	...	...	...	...	...	4
16. Crania............	8	1	2	2	2	...	2	...	...	...	...	...	...	...	9
Total	16 275	10 36	14 74	11 47	10 90	4 14	9 26	3 10	4 19	5 10	5 10	7 21	4 10	3 3	89 370

LAMELLIBRANCHIATA. *Monomyaria.*—9 genera and 19 species occur. 12 of the 19 appear only in the Portlandian rocks, no species passing to the Purbecks; the remaining 7 species come either from the Corallian or Kimmeridgian beds below, and 6 species actually connect the two formations; they are named in the analysis of the Kimmeridge Monomyaria.

Dimyaria.—26 genera and 55 species occur, 42 of which are strictly Portlandian. 10 species come direct from the Kimmeridge Clay; they are named under the Kimmeridge analysis; the remaining 3 are Corallian. As in the Monomyaria, no species pass above the Portland rocks. The genera *Trigonia, Lucina,* and *Pholadomya* play an important part in the Upper Jurassic rocks.

Gasteropoda.—As we have seen in the Oxford Clay, the Corallian beds, and the Kimmeridge Clay, so now in the Portland, the species all belong almost entirely to their own special horizons, *Turritella minuta* being the only species said to be common to the Kimmeridge and Portland out of the 10 genera and 19 species occurring.

Cephalopoda. *Ammonites.*—11 species occur, and 7 are Portlandian only; they are *Am. boloniensis, Am. giganteus, Am. gigas, Am. Gravesianus, Am. ireus, Am. pectinatus, Am. pseudo-gigas.*

The 4 species uniting the Kimmeridge and Portland beds are *Am. triplex, Am. triplicatus, Am. hector,* and *Am. biplex*; all the species disappear with the close of the Upper Jurassic Period. The genus *Perisphinctes* is well represented among the Portland Ammonites.

Nautili.—None known.

Belemnites.—None known.

Teuthidæ.—None known.

Table XLII.—*Showing the Numerical and Stratigraphical Value of the whole of the Jurassic Mollusca.*

Classes.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian Beds.	Kimmeridge Clay.	Portlandian.
Brachiopoda	10 / 36	14 / 74	11 / 47	10 / 90	4 / 14	9 / 26	3 / 10	4 / 19	5 / 10	5 / 10	7 / 21	4 / 10	3 / 3
Monomyaria	18 / 114	16 / 60	13 / 32	15 / 106	9 / 15	16 / 80	9 / 24	11 / 55	11 / 28	9 / 26	14 / 58	11 / 42	9 / 19
Dimyaria	36 / 138	34 / 108	25 / 69	47 / 236	22 / 51	40 / 185	19 / 33	33 / 98	18 / 57	21 / 48	29 / 93	26 / 58	26 / 55
Gasteropoda	41 / 226	27 / 136	19 / 55	41 / 240	1 / 1	40 / 247	19 / 43	20 / 28	10 / 19	10 / 17	21 / 67	12 / 23	10 / 19
Ammonites	1 / 173	1 / 54	1 / 79	1 / 42	1 / 5	1 / 7	1 / 2	1 / 3	1 / 41	1 / 45	1 / 21	1 / 31	1 / 11
Nautili	1 / 6	1 / 4	1 / 3	1 / 6	...	1 / 3	...	1 / 1	1 / 2	...	1 / 1		
Belemnites............	1 / 21	1 / 27	1 / 34	1 / 16	1 / 3	1 / 3	...	...	1 / 3	1 / 13	1 / 4	1 / 8	
Teuthidæ	1 / 1	1 / 1	1 / 2	...	...	...	...	...	...	2 / 2	...	1 / 1	
Total	109 / 715	95 / 464	72 / 321	116 / 736	38 / 89	108 / 551	51 / 118	70 / 204	47 / 160	49 / 161	74 / 265	56 / 173	49 / 107

Pisces.—*Gyrodus Cuvieri, Hybodus striatus, Ischyodus Egertoni, I. Townshendii*, and *Pycnodus pagoda* are the 4 genera and 5 species known. *Gyrodus Cuvieri* also occurs in the Coral Rag.

Reptilia.— *Ceteosaurus longus, Megalosaurus Bucklandi, Goniopholis* sp., *Plesiosaurus carinatus, P. winspitensis*, and *Pliosaurus portlandicus* are all the Reptilia known. Except *Meg. Bucklandi* all are strictly Portlandian.

Table XLIII.—*Analysis and Distribution of the Portlandian Species.*

From Kimmeridge Clay.		Classes.	Genera.	Species.	
		Plantæ. } None.			No Species in any Class passes to higher strata.
		Amorphozoa. } None.			
		Rhizopoda. } None.			
		Cœlenterata	1	1	
		Echinodermata	2	3	
$\frac{1}{1}$		Annelida	1	4	
		Crustacea	1	2	
		Bryozoa (none).			
		Brachiopoda	3	3	
$\frac{3}{6}$	35 genera and 74 species.	Monomyaria	9	19	
$\frac{7}{10}$		Dimyaria	26	55	
		Gasteropoda	10	19	
$\frac{1}{4}$	Cephalopoda.	Ammonites	1	11	
		Nautili. } None.			
		Belemnites. } None.			
		Teuthidæ. } None.			
		Pisces	4	5	
		Reptilia	5	6	
		Mammalia (none).			
$\frac{13}{22}$		....	63	128	

The accompanying Table XLIV. shows at once the numerical value of the whole fauna and flora of the British Jurassic rocks; the

[*To face* p. 226.

n Britain.

	Kellaways Rock.	Oxford Clay.	Corallian beds.	Kimmeridge Clay.	Portlandian.	Occurrences or appearances.
	...	1 1	4 7	1 1	...	79 191
	...	...	2 2	...	...	7 12
	...	3 3	1 1	7 13	...	55 182
	...	...	10 14	...	1 1	70 189
	1 3	3 3	15 28	3 7	2 3	127 250
	1 1	1 2	2 7	2 3	1 4	19 59
	1 2	5 6	1 2	6 7	1 2	41 75
	...	...	2 2	...	...	38 66
	5 10	5 10	7 21	4 10	3 3	89 370
Lamellibran- chiata 95 genera and 1368 species.	11 28	9 26	14 58	11 42	9 19	161 659
	18 57	21 48	29 93	26 58	26 55	376 1235
	10 19	10 17	21 67	12 23	10 19	271 1121
	1 41	1 45	1 21	1 31	1 11	13 514
	1 1	1 1	...	...	...	3 3
Cephalopoda	1 2	...	1 1	...	...	8 26
	1 3	1 13	1 4	1 8	...	10 132
	...	2 2	...	1 1	...	6 7
	1 1	3 4	2 3	11 14	4 5	94 218
	...	7 13	3 3	17 45	5 6	60 144
	...	...	...	...	...	4 6
	52 168	73 194	116 334	103 263	63 128	1531 5459

TABLE XLIV.—*Showing the whole Fauna and Flora of the Jurassic Rocks in Britain.*

Classes &c.	Number of Genera.	Number of Species.	Lower Lias.	Middle Lias.	Upper Lias.	Inferior Oolite.	Fuller's Earth.	Great Oolite.	Forest Marble.	Cornbrash.	Kellaways Rock.	Oxford Clay.	Corallian beds.	Kimmeridge Clay.	Portlandian.	Occurrences or appearances.
Plantæ	63	191	11/15	...	1/2	41/130	...	20/55	...	...	...	1/1	4/7	1/1	...	79/191
Amorphozoa	5	11	1/1	...	...	...	...	4/9	...	...	...	...	2/2	...	...	7/12
Rhizopoda	23	100	20/64	14/48	10/33	...	...	...	...	...	...	3/3	1/1	7/13	...	55/162
Cœlenterata	38	175	13/72	6/8	2/2	19/48	2/4	15/38	1/1	1/1	...	...	10/14	...	1/1	70/199
Echinodermata	47	216	11/15	14/29	9/14	22/51	8/11	22/53	6/10	12/23	1/3	3/3	15/28	3/7	2/8	127/250
Annelida	3	45	1/6	2/5	1/2	3/11	1/3	2/7	1/1	1/5	1/1	1/2	2/7	2/3	1/4	19/59
Crustacea	24	64	13/33	1/1	6/12	2/2	...	5/5	...	1/3	1/2	5/6	1/2	6/7	1/1	41/75
Bryozoa	19	51	3/4	1/1	1/1	7/17	3/3	16/31	2/2	4/5	...	...	2/2	...	...	38/66
Brachiopoda	16	275	10/35	14/74	11/47	10/90	4/14	9/26	3/10	4/19	5/10	5/10	7/21	4/10	3/3	80/370
Lamellibranchiata, 95 genera and 1368 species: Monomyaria	25	444	18/114	16/60	13/32	15/106	9/15	16/90	9/34	11/55	11/28	9/26	14/58	11/42	9/19	161/659
Lamellibranchiata: Dimyaria	70	924	36/138	34/109	35/60	47/236	22/61	40/185	10/39	33/98	18/57	21/48	29/93	26/58	20/55	376/1235
Gasteropoda	76	1015	41/220	27/136	19/55	41/240	1/1	40/247	19/43	20/28	10/19	10/17	21/67	12/23	10/19	271/1121
Cephalopoda: Ammonites	1	477	1/173	1/54	1/79	1/42	1/5	1/7	1/2	1/3	1/41	1/46	1/21	1/31	1/11	13/514
Cephalopoda: Ancyloceras	1	1	...	...	...	1/1	...	...	...	...	1/1	1/1	...	...	...	3/3
Cephalopoda: Nautili	1	21	1/6	1/4	1/3	1/6	...	1/3	...	1/1	1/2	...	1/1	...	...	8/26
Cephalopoda: Belemnites	1	115	1/21	1/27	1/34	1/15	1/3	1/3	...	...	1/3	1/13	1/4	1/8	...	10/132
Cephalopoda: Teuthidæ	5	6	1/1	1/1	1/2	...	...	...	...	...	...	2/2	...	1/1	...	6/7
Pisces	61	219	40/106	2/2	6/18	2/4	...	20/58	1/1	2/2	1/1	3/4	3/3	11/14	4/5	94/218
Reptilia	30	132	5/23	2/5	4/13	...	...	13/27	3/3	1/1	...	7/13	3/3	17/45	5/6	60/144
Mammalia	4	6	...	...	...	...	...	4/6	...	...	...	...	...	...	...	4/6
	513	4488	226/1081	137/563	111/418	213/1000	51/110	229/820	65/136	92/244	52/168	73/194	116/334	103/263	63/128	1531/5459

total number of genera and species known in the several Classes is stated in the two left-hand columns, and all through the Table the numbers of genera and species are expressed in their respective horizons or formations, from the Lower Lias to the Portland Beds. Each individual square in the Table states the value of both genera and species expressed fractionally, the upper figures stating the number of genera in the Class, and the lower the number of species. These will be found to agree with the text all through my address when named. This Table is suggestive, and shows how much has been done in the Jurassic rocks and how much has still to be done to fill in the wanting genera and species. The right-hand column gives the number of occurrences or appearances of genera and species in the several Classes through time. This census of the Jurassic species, brought down to 1882, may form the basis of comparison at some future date when it is deemed of sufficient interest (perhaps in another twenty years) to show the increase of the fauna and flora of the Lower Secondary Rocks of the British Islands.

TABLE XLV.—*Showing the whole number of Genera and Species known in the Jurassic Rocks; and also the whole occurrences and appearances of both the Genera and Species.*

(This Table and Table XLVI. are both compiled from the chief total results given in Table XLIV.)

Classes.	Known number of		Occurrences of	
	Genera.	Species.	Genera.	Species.
Plantæ	63	191	79	191
Amorphozoa	5	11	7	12
Rhizopoda	23	100	55	182
Cœlenterata	38	175	70	189
Echinodermata	47	216	127	250
Annelida	3	45	19	59
Crustacea	24	64	41	75
Bryozoa	19	51	38	66
Brachiopoda	16	275	89	370
Monomyaria	25	444	161	659
Dimyaria	70	924	376	1235
Gasteropoda	76	1015	271	1121
Ammonites	1	477	13	514
Ancyloceras	1	1	3	3
Nautili	1	21	8	26
Belemnites	1	115	10	132
Teuthidæ	5	6	6	7
Pisces	61	219	94	218
Reptilia	30	132	60	144
Mammalia	4	6	4	6
	513	4488	1531	5459

TABLE XLVI.—*Number of Genera and Species occurring in the whole of the Jurassic Rocks arranged stratigraphically, or from the Lower Lias to the close of the Portland Oolite.*

Formations.	Genera.	Species.
Lower Lias	226	1081
Middle Lias	137	563
Upper Lias	111	418
Inferior Oolite	213	1000
Fuller's Earth	51	110
Great Oolite	229	820
Forest Marble	65	136
Cornbrash	92	244
Kellaways Rock	52	168
Oxford Clay	73	194
Corallian beds	116	334
Kimmeridge Clay	103	263
Portland Oolite	63	128
	1531	5459

§ 14. THE MODERN CLASSIFICATION OF AMMONITES.

The modern classification of the Ammonitidæ is by no means an easy one to elaborate after the long usage of the present nomenclature. Von Buch * attempted a better arrangement than had before appeared, based upon the definite ramifications and foliations of the suture or lobe-line, which is traceable beneath the shell or upon the mould, the characters of the lobes and saddles formed by them, the position and structure of the siphuncle, and the form of the spiral of the shell. Upon these elements he constructed his 21 groups of the Ammonitidæ, which for years have been the foundation of all attempts at the classification of the Ammonites. D'Orbigny, Quenstedt, and others enlarged upon the method of Von Buch. Professor Suess †, Dr. W. Waagen ‡, Prof. Hyatt, of America §, M. E. Favre ||, Prof. Neumayer ¶, Dr. Mojsisovics **, Prof. Zittel, Dr. Laube, and others, however, have all carried out the views and classification of the Vienna school. The characters upon which the genera are established are:—1st, *the structure of the lobes and saddles*; 2nd, *the form of the aperture of the shell and the development of the mouth-border*; 3rd, *the length of the body-chamber*; 4th, *the amount*

* 'Die Ammoniten in den älteren Gebirgs-Schichten,' 1830.

† "Ueber Ammoniten," Erste Abth., Sitzungsber. der Math.-nat. Classe der Wiener Akad. 1865, Band lii. Abth. 1.

‡ "Ueber die Ansatzstelle der Haftmuskeln beim Nautilus und den Ammoniden," Palæontographica, Band xvii. Abth. 5, p. 197 (1867–70).

§ Bulletin of the Mus. of Comp. Anatomy, Harvard Coll., Cambridge, Mass., vol. i. no. 5 (1866).

|| "Sur la Classif. des Ammonites," Bull de la Soc. Géol. de France, 3e séries, tome 1 (1873).

¶ Zeitschrift der deutschen geologischen Gesellschaft, p. 854, Jahrgang 1875; und Die Ammoniten der Kreise und die Systematik der Ammonitiden.

** Das Gebirge um Hallstatt (Wien, 1875).

of involution of the whorls; 5th, *the presence or absence of the aptychus, its form and structure.* In all the Ammonitidæ the position of the siphuncle is invariably in the centre of the abdomen, and in the outer margin of the shell (*back or keel of old authors*) opposite to the columella or dorsal border. The spiral described by the growth of the shell was taken as the basis for the establishment of several genera by the older authors, Lamarck, Parkinson, von Hauer, D'Orbigny, Leveillé, &c. No less than 16 genera have been thus characterized, but in conjunction with other characters it becomes subordinate. Prof. Neumayer (*loc. cit.*) proposed a classification grouped into the four families ARCESTIDÆ, TROPITIDÆ, LYTOCERATIDÆ, and ÆGOCERATIDÆ.

The family Arcestidæ includes the forms occurring abundantly in the Triassic strata of the eastern Alps and those in the Red Triassic Alpine Limestone at Hallstatt. Only one genus (*Amaltheus*) of this family occurs in Britain. The remaining 7 genera differ essentially from any known, either in the Jurassic or Cretaceous rocks.

The members of the second family (Tropitidæ) are all Triassic, and do not occur in Britain.

The Lytoceratidæ include many diverse groups, especially as regards their external form. The genera *Hamites*, *Turrilites*, *Baculites*, and *Phylloceras* belong here, all occur in Britain and in the Cretaceous rocks. *Phylloceras* is also Upper and Middle Lias.

The Ægoceratidæ include many groups widely differing in general form and structure ; they may be naturally classed under 3 sections, which will be noticed hereafter.

Fam. I. ARCESTIDÆ.

Contains 8 genera :—1. *Arcestes* ; 2. *Didymites* ; 3. *Lobites* ; 4. *Ptychites* ; 5. *Pinacoceras* ; 6. *Sageceras* ; 7. *Amaltheus* ; 8. *Schlœnbachia.*

Of the above 8 genera *Amaltheus* is the only British genus. It has a very extensive range in time, as it occurs in the Trias, and is largely developed in the Jurassic rocks, commencing in the Lias with *Amal. Guibalianus*, D'Orb., *Amal. margaritatus*, Brug., and *Amal. spinatus*, Sow. Many species also occur in the Cretaceous rocks, such as *Amal. Gervillianus*, D'Orb., *Amal. Vibrayeanus*, D'Orb. ; the well-known *Amal. oxynotus*, *Am. Simpsoni*, and *Am. impendens* are all Lower Lias. *Amal. Oppeli* is from the same horizon.

Genus *Schlœnbachia.*—Limited to the Cretaceous rocks ; in Britain the old group *Cristati* contains the species. The typical form is *Schlœnbachia cristata.*

The genera *Arcestes*, *Didymites*, *Lobites*, *Ptychites*, *Pinacoceras*, and *Sageceras* possess no British species, and most of them are Triassic genera.

Fam. II. TROPITIDÆ.

Contains 5 genera :—1. *Tropites* ; 2. *Trachyceras* ; 3. *Choristoceras* ; 4. *Rhabdoceras* ; and 5. *Cochloceras.*

None of these genera include British species.

Fam. III. Lytoceratidæ.

Contains 5 genera, all of which are British, and as such I must notice them.

The genera of the Lytoceratidæ differ greatly from each other in external form, but have close relations in their internal structure. The body-chamber is short ($\frac{2}{3}$ of whorl), with simple mouth-border, produced on the columellar side.

This family includes the typical genera *Lytoceras* and *Phylloceras*, the former represented by *L. fimbriatum*, Sow., from the Middle and Upper Lias, and the latter by *Phylloceras heterophyllum* from the Upper Lias. The remaining 3 genera are *Hamites*, *Turrilites*, and *Baculites*, all Cretaceous, and differing essentially in external form.

Lytoceras commences in the Trias with *Lyt. Maloti* and *Lyt. patens*. It is represented in the Lias by *Lyt. fimbriatum*, Sow., *Lyt. cornucopia*, *Lyt. jurense*, Ziet., *Lyt. lineatum*, Schloth., *Lyt. hircinum*, Schloth., and *Lyt. torulosum*, and by *Lyt. Eudesianum*, D'Orb., in the Inferior Oolite. In the Lower Cretaceous rocks this genus is represented by *Lyt.* (*Crioceras*) *Duvalianum* and *Lyt. subfimbriatum*, D'Orb.

Genus *Hamites*.—Prof. Neumayer does not believe that "a spiral curve of a particular form gives sufficient warrant for the establishment of a distinct genus. Adopting this view, the 7 old and recognized genera (*Anisoceras*, *Ancyloceras*, *Baculina*, *Hamulina*, *Helicoceras*, *Ptychoceras*, and *Toxoceras*), in which the curvature receives many modifications, and exists in some in more than one plane, are now suppressed, and the whole series reduced to the single genus *Hamites*, which is a conical straight shell (ex. *H. elegans*, D'Orb.) bent in one plane, the bends or curves not in contact. The suture-line is divided into six lobes, and the chief or under lateral lobe is divided into pairs of branches.

Genus *Turrilites*.—Neumayer under this genus classes *Helicoceras* with an open spiral, not on one plane. In *Turrilites* the suture-line is divided into six lobes, each lobe possessing a single pair of digitations, and the mouth is simple and the shell sinistral.

Genus *Baculites*.—Neumayer connects this genus with *Lytoceras* and *Hamites* by the structure of the principal lateral lobe. The septa are symmetrical, divided into four or six lobes, each having a pair of digitations (type *B. anceps*).

Genus *Phylloceras*.—In this fine genus the body-chamber is short, and the mouth-border with lateral forwardly directed lappets. Lobes numerous, eight or nine on each side, very complicated. *Phylloceras heterophyllum*, Sow., from the Upper Lias, is the type. Neumayer distinguishes 4 groups in this genus; the following are his types:—

1. *Phylloceras heterophyllum*, Sow.
2. *P. tatricum*, Pusch.
3. *P. Capitanei*, Catullo.
4. *P. ultramontanum*, Zittel.

Phylloceras commences in the Trias; but no British Triassic species is known. *P. Loscombi*, Sow., occurs in the British Middle Lias; and *P. heterophyllum*, Sow., and *P. subcarinatum*, Young, in the Upper Lias. In the Cretaceous rocks the only British forms are *P. Velledæ* and *P. lewesiense.*

Fam. IV. ÆGOCERATIDÆ.

Includes several groups having widely different forms.

This family is divided into 3 subfamilies:—

Subfam. 1. *Ægoceratites.*

2 genera: *Arietites* and *Ægoceras.*

Subfam. 2. *Harpoceratites.*

3 genera: *Harpoceras*, *Oppelia*, and *Haploceras.*

Subfam. 3. *Stephanoceratites.*

15 genera: *Stephanoceras*, *Cosmoceras*, *Ancyloceras*, *Baculina*, *Simoceras*, *Perisphinctes*, *Oleostephanus*, *Scaphites*, *Hoplites*, *Acanthoceras*, *Stoliczkaia*, *Crioceras*, *Heteroceras*, *Peltoceras*, and *Aspidoceras.*

Subfam. 1. *Ægoceratites.*

Genus *Ægoceras*, a large and important genus in the British rocks, especially in the Lower and Middle Lias. *Ægoceras* may be divided into 4 sections based upon the structure of the shell.

Section 1. *Psilonoti.*
,, 2. *Angulati.*
,, 3. *Armati.*
,, 4. *Involuti.*

Sect. 1. *Psilonoti.*—Essentially Lower Lias and in the lowest zone (*Planorbis*).

In all the species of this section the keel is absent, and there are no lateral longitudinal channels in the siphonal or ventral area. The lobe-line is much ramified, and the lobes are complicated. The species are the well-known forms *Æg. planorbis*, Sow., *Æg. Johnstoni*, Sow., *Æg. torus*, D'Orb., *Æg. intermedium*, Portl., *Æg. Belcheri*, Simp., and *Æg. liassicum*, D'Orb. These forms all occur in the zone of *Æg. planorbis*, at the extreme base of the Lias. They range through Britain wherever these lowest beds are observed.

Sect. 2. *Angulati.*—This is an extremely well-defined section. The sharply flexed ribs and deep channel on the ventral area distinguish the species of *Ægoceras* belonging to this section. The chief species are *Æg. angulatum*, *Æg. Charmassei*, and *Æg. catenatum*, all of which occur in the zone of *Æg. angulatum*. *Æg. lacunatum* and *Æg. Boucaultianum*, D'Orb., with *Æg. Birchii*, are from the succeeding or higher zone of *Arietites Bucklandi*, the whole being Lower Lias and British.

Sect. 3. *Armati.*—An important section in Britain and Germany. The ribs on the sides of the shell develop tubercles or long spines in many species. This section is almost entirely Middle Lias, but *Æg. Birchii* and *Æg. planicosta* characterize the zone of *Arietites Bucklandi* in the Lower Lias, whereas *Æg. Davœi*, *Æg. armatum*, *Æg. Taylori*, *Æg. densinodus*, *Æg. brevispinum*, *Æg. Valdani*, and *Æg. Maugenesti* are all British Middle-Lias species, and from the zone of *Æg. Jamesoni*, Sow.

Sect. 4. *Involuti.*—The shell in this section of *Ægoceras* is highly involute; the inner whorls are almost entirely concealed in some forms; in others the umbilicus is much wider, through the involutions being less. The zone of *Æg. Henleyi* yields the following species:—*Æg. striatum*, *Æg. Bechei*, *Æg. pettos*, and *Æg. heterogenes*, Y. & B. The species are essentially Middle Lias and British. The first appearance of this section is in the Muschelkalk; it became extinct in the Middle Lias.

Genus *Arietites* (the group "Arietes" of Von Buch, highly characteristic of the Lower Lias, and in which we know of at least 20 species).—Waagen established this genus (*Arietites*) for those species having a wide and open umbilicus, the sides of the shell also possessing straight simple ribs, which often bear tubercles near the ventral angle, as in *A. rotiformis*. The keel is large and prominent, having on each side a deep lateral channel or groove. The following 20 important species belong to the genus *Arietites*:—

Arietites Bucklandi, *Sow.*	Arietites rotiformis, *Sow.*
—— Bodleyi, *Buckm.*	—— Sauzeanus, *D'Orb.*
—— Bonnardi, *D'Orb.*	—— stellaris, *Sow.*
—— Crossii, *Wright.*	—— Scipionianus, *D'Orb.*
—— obtusus, *Sow.*	—— impendens, *Y. & B.*
—— semicostatus, *Simp.*	—— Conybeari, *Sow.*
—— bisulcatus, *Brug.*	—— Brookii, *Sow.*
—— raricostatus, *Ziet.*	—— Turneri, *Sow.*
—— multicostatus, *Sow.*	—— obesulus, *Blake.*
—— Collenoti, *D'Orb.*	—— Nodotianus, *D'Orb.*

No genus of Ammonites in the British rocks is more important stratigraphically. None of the species pass the horizon of the Lower Lias; and they essentially characterize its lower members. 12 of the 20 species occur in the cliff-section at Lyme Regis; few sections are opened in the Lower Lias in which they are not met with.

Subfam. 2. *Harpoceratites.*

Genus *Harpoceras.*—This is in part equivalent to the group *Falciferi* of Von Buch, which in Britain attains its highest development in the Upper Lias, equalling in stratigraphical importance the genus *Arietites* in the Lower Lias. *Harpoceras* first appears in the Middle Lias with *Ægoceras Jamesoni* in 3 well-determined species—*H. impendens*, *H. Normanianum*, and *H. arietiforme.* The two first-named are British species. *Harpoceras* occurs also in the Middle and Lower Jurassic rocks, associated with

"*Pterocera oceani.*" At least 20 species of *Harpoceras* occur in the Upper Lias of Britain, and 4 in the Inferior Oolite. *Harpoceras* cannot be mistaken for any other genus; the ventral area is always keeled; the sides of the shell ornamented with *falciform ribs*; mouth-border sickle-shaped, with lateral auricles or expansions, and a long pointed rostrum-like ventral process. Many other characters I cannot here describe.

The Upper-Lias species of *Harpoceras* are:—

Harpoceras falciferum.	Harpoceras insigne.
—— serpentinum.	—— radians.
—— bifrons.	—— striatulum.
—— lythense.	—— concavum.
—— variabile.	—— aalense.
—— ovatum.	—— thouarsense.
—— Levisoni.	—— primordiale.
—— Beanii.	—— subconcavum.
—— elegans.	—— exaratum.
—— opalinum.	

The *Harpocerata* from the Inferior Oolite are:—

Harpoceras Murchisonæ.	Harpoceras Sowerbyii.
—— Tessonianum.	—— Edwardianum.

Genus *Oppelia*, Waagen.—A rare genus in the British Islands, which first occurs in the Inferior Oolite. In India many species have been described by Dr. Waagen. The "Golden Oolite" of Keera Hill, Kutch, and other higher strata have yielded a rich harvest of species of *Oppelia*. The most characteristic British forms are *O. subradiata*, Sow., and *O. discus*, Sow.; the latter is a Cornbrash species. *Oppelia* has a wide stratigraphical range, from the lower to the uppermost stages of the Jurassic series; it is also Neocomian and Upper Cretaceous.

Genus *Haploceras*, Zittel.—Separated from *Oppelia* by marked characters: well-defined lines of growth and narrow umbilicus, no bifurcation of ribs, no keel or channel in the siphonal area, with peculiar conditions of the lobes, serve to distinguish this genus. The group *Ligati*, D'Orb., in part belongs here. The Inferior-Oolite forms *Hapl. ooliticum*, D'Orb., and *Hapl. ligatum*, D'Orb., are examples of the species.

Subfam. 3. *Stephanoceratites.*

Genus *Stephanoceras.*—The species of this large genus are essentially Lower Jurassic. They commence in the Upper Lias with *S. commune*, *S. annulatum*, *S. crassum*, *S. Holandrei*, *S. fibulatum*, &c. The base of the Inferior Oolite teems with individuals; and both in France and England the zone of *S. Humphriesianum* is the home for numerous forms. The species in Von Buch's groups xviii. (the *Planulati*), xix. (the *Coronarii*), and xx. (the *Macrocephali*) have been partly absorbed recently into the genus *Stephanoceras*. This is at once manifest from the following list of species:—

Stephanoceras Blagdeni.	Stephanoceras Deslongchampsii.
—— Braikenridgii.	—— Gervillii.
—— Brocchii.	—— Humphriesianum.
—— coronatum.	—— Sauzei.
—— Brongniarti.	—— Banksii.

The globose form of *Stephanoceras macrocephalum* represents a distinct group, characterized by the smallness of the umbilicus, extreme involution of the shell, and long siphonal lobe. *Steph. modiolare* possesses the same lobal conditions. This group of the *Stephanocerata* is not specifically rich in the European rocks, and occupies a limited horizon in time. In England and Germany the above group commences in the Cornbrash, and occurs in the Kellaways Rock and Oxford Clay. Dr. Waagen, in the "Jurassic Cephalopoda" (Palæontologia Indica), has figured and described 23 species of *Stephanoceras* from the "Kacch Jura;" of these, the species identical with European forms occupy also in Kacch, as in Europe, the true "*Macrocephalus*-beds." The group of the *Macrocephali* is one of the most important among all the Jurassic Ammonites, for nearly-allied forms have been found over the whole world.

Genus *Cosmoceras*.—Von Buch's group x. (the *Ornati*) is absorbed by *Cosmoceras*. This genus first appears in the upper beds of the Inferior Oolite, where the species *Cosm. Parkinsoni* and *Cosm. Garantianum* abound; they are well characterized by the smooth channel in the middle of the ventral side, which interrupts the passing of the ribs across the siphonal area. In the Kellaways and Oxford Clay *Cosmoceras calloviense*, *C. Duncani*, *C. Kœnigi*, *C. Gowerianum*, and *C. jason* abound. The highly ornamented shells and other constant characters well deserved the name applied to the group by Von Buch. The genus ranges into the Chalk under the form of *Cosm. verrucosum*, D'Orb.

Genus *Ancyloceras*, D'Orb.—Spirally rolled on the same plane, the "whorls all disjointed and separate," the last projected in a horizontal direction, then turning upwards and inwards, opposed or opposite to the spiral coil; the septa are transverse, symmetrical, and 6-lobed, unequal in size, and composed of ramified elongated digitations. The earliest form known is *Ancyloceras annulatum*, from the Lower Jurassic beds of England and France; with it, in the Inferior Oolite of Germany, occurs *Ancyl. baculatum*. The Kellaways Rock yields one, *Ancyl. calloviense*. *Ancyloceras* attains its greatest development in the Lower Cretaceous rocks (Neocomian), the two chief forms being *Ancyl. Matheronianum* and *Ancyl. Puzosianum*. *Ancyl. gigas*, *Hillsii*, *grande*, and *Matheronianum* are British Cretaceous species.

Genus *Perisphinctes*, Waagen.—The singular Ammonite *P. Martinsii*, D'Orb., from the Inferior Oolite of England and France, is the only example we have. Dr. Waagen enumerates nearly 60 species from the Kacch Jura (Cutch). "These can be distributed into 6 large sections, comprising several groups that find their equivalents in the Middle and Upper Jurassic rocks of Europe, between

the Kellaway, Oxford, Corallian, Kimmeridgian, and Portlandian stages."

Genus *Scaphites*, Park.—This genus, like *Ancyloceras*, needs little notice here. All the species are Cretaceous.

Genus *Hoplites*, Neum.—The highly ornamented shells of this genus form conspicuous groups in the Cretaceous rocks, of which they are characteristic. The old groups *Tuberculati* and *Dentati* partly fall into the genus *Hoplites*. The "Dentati interrupti" would receive certain forms of *Hop. interruptus* and *Hop. splendens*, *Hop. falcatus* being one of the known "*Tuberculati*." The Gault, Upper Greensand, and Lower Chalk contain the genus *Hoplites*.

Genus *Acanthoceras*, Neumayer.—Neumayer instituted this new group to receive certain species once included in the genus *Hoplites*. In the old classification many were placed by D'Orbigny in his group vii. (*Rhotomagenses*), and by Pictet in group ix. (*Dentati*, Von Buch). The siphonal area varies considerably; in some the median line is channelled and with rows of tubercles on the border, thus interrupting the ribs from crossing the ventral margin, or the tubercles are arranged in rows, or pass along the median line in a kind of knotted keel. This short diagnosis will suggest *A. mammillare*, *A. rhotomagense*, *A. sussexense*, and *A. Mantelli* under the old classification, groups vii. and ix. All the species are Cretaceous.

Acanthoceras Mantelli.	British species.
—— rhotomagense.	
—— sussexense.	
—— Woolgari.	
—— mammillare.	
—— Brottianum.	French species.
—— Deverianum.	
—— Martinsii.	

Genus *Stoliczkaia*.—All are Indian species in this genus. Neumayer established this group to receive some remarkable Ammonites figured in Stoliczka's great work "*On the Ammonitidæ of the Chalk Rocks of Southern India*" [vide this work for the types of the genus].

The genera *Crioceras*, Leveillé, *Toxoceras*, D'Orb., and *Heteroceras*, D'Orb., need only be mentioned; they have no special value in the modern nomenclature of the Ammonitidæ.

Genus *Aspidoceras*, Zittel.—Von Buch's group xiii. (*Armati*) embraces the species of *Aspidoceras*. The chief species are *Asp. longispinum*, from the Kimmeridge and Oxford Clays, *Asp. perarmatum*, Oxfordian and Corallian; this last species is the type of a large section. D'Orbigny's type for the *Perarmati* is *Asp. altenense*, a Corallian form.

Genus *Peltoceras*, Waagen.—In England the genus *Peltoceras* is confined to the Oxfordian stage, and only 2 species represent it—*P. athleta*, Phill., and *P. Williamsoni*, Phill.

Genus *Simoceras*, Zitt.—Reinecke's species, *S. anceps*, is a British species ranging through the Oxfordian stage; it is possibly the *Am.*

(Sim.) coronatus of Schlotheim, and the *Am. dubius* of Zieten. It would have taken up so much space to have described at any length the foregoing genera of the Ammonitidæ that all save necessary matter is omitted. This subject alone is so large a one, and its bearing upon stratigraphical geology so important, that I deemed it right to notice it, but at the same time to reduce the matter to its smallest limits. The most important *résumé* of the modern classification is given in vol. xxxiii. of the Memoirs of the Palæontographical Society by Dr. Wright, F.R.S.; he has embodied the researches of Suess, Neumayer, Waagen, Hyatt, Mojsisovics, D'Orbigny, &c. It is the only English digest we have upon the modern classification of this division of the Cephalopoda, and which gives us the views of continental palæontologists. Messrs. Tate and Blake, in their work on the Yorkshire Lias, have ably treated of the Ammonitidæ of that formation.

February 22, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Richard Kerr, Esq., 19 Copt Hall Place, Folkestone; Baron Ferd. von Müller, K.C.M.G., M.D., Ph.D., F.R.S., Director of the Botanic Gardens, Melbourne; William Whitehead Watts, Esq., B.A., Broseley, Shropshire; and Joseph Wilkinson, Esq., F.R.G.S., Coney Street, York, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Additional Discoveries of High-level Marine Drifts in North Wales, with Remarks on Driftless Areas." By D. Mackintosh, Esq., F.G.S.

2. "On some Sections of Lincolnshire Neocomian." By H. Keeping, Esq., of the Woodwardian Museum, Cambridge. Communicated by W. Keeping, Esq., M.A., F.G.S.

3. "Notes on the Geology of the Cheviot Hills (English side)." By C. T. Clough, Esq., M.A., F.G.S.

The following specimens were exhibited :—

Rock-specimens and sections exhibited by Mr. Clough, in illustration of his paper.

Specimens from the Woodwardian Museum, Cambridge, exhibited by E. B. Tawney, Esq., in illustration of Mr. Keeping's paper.

March 8, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

George Clementson Greenwell, Esq., Jun., Poynton, near Stockport, and John Baldry Redman, Esq., M.Inst.C.E., 6 Queen Anne's Gate, Westminster, S.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Additional Note on certain Inclusions in Granite." By J. Arthur Phillips, Esq., F.R.S., F.G.S.

2. "The Geology of Madeira." By J. S. Gardner, Esq., F.G.S.

3. "On the Crag Shells of Aberdeenshire and the Gravel Beds containing them." By Thomas F. Jamieson, Esq., F.G.S.

4. "On the Red Clay of the Aberdeenshire coast, and the direction of Ice-movement in that quarter." By Thomas F. Jamieson, Esq., F.G.S.

Specimens were exhibited by J. Arthur Phillips, Esq., and by J. Starkie Gardner, Esq., in illustration of their papers.

March 22, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

William Brown, Esq., 28 Holland Road, Kensington, W.; George Thomas Parnell, Esq., Montague House, Enfield, and 22 Charing Cross, S.W.; and Edwin Alfred Walford, Esq., West Bar Street, Banbury, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On a Fossil Species of *Camptoceras*, a Freshwater Mollusk, from the Eocene of Sheerness." By Lt.-Colonel H. H. Godwin-Austen, F.R.S., F.G.S.

2. "Note on the Os Pubis and Ischium of *Ornithopsis eucamerotus* (synonyms—*Eucamerotus*, Hulke; *Bothriospondylus* (in part), R. Owen; *Chondrosteosaurus*, R. Owen)." By J. W. Hulke, Esq., F.R.S., Pres.G.S.

3. "On *Neusticosaurus pusillus* (Fraas), an Amphibious Reptile having Affinities with the Terrestrial Nothosauria and with the Marine Plesiosauria." By Prof. H. G. Seeley, F.R.S., F.G.S.

Specimens were exhibited by Lieut.-Colonel Godwin-Austen in illustration of his paper.

April 5, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

W. J. H. Mylne, Esq., C.E., 2 Middle Scotland Yard, S.W., was elected a Fellow, and M. Alphonse Milne-Edwards, of Paris, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "Geological Age of the Taconic System." By Prof. J. D. Dana, F.M.G.S.

2. "On some Nodular Felsites in the Bala Group of North Wales." By Prof. T. G. Bonney, M.A., F.R.S., Sec.G.S.

3. "On the Cambrian (Sedgw.) and Silurian Rocks of Scandinavia." By J. E. Marr, Esq., B.A., F.G.S.

Rock-specimens and sections were exhibited by Prof. Bonney in illustration of his paper.

April 16, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

The President remarked that it would argue a degree of indifference with which the Society could not be charged, if the Meeting were to proceed to the transaction of the ordinary business without some reference to the sad loss sustained by the whole scientific world within the last few days in the death of the illustrious naturalist whose remains had been consigned that morning to their last resting-place at Westminster. He added that the spectacle presented by the vast assemblage of people who came together to witness the obsequies of Mr. Darwin was of the most soul-stirring kind, and constituted the grandest conceivable testimony of respect for the memory of the distinguished philosopher who had just passed from among us.

S. S. Buckman, Esq., Bradford Abbas, Sherborne, Dorset; Hugh Salvin Holme, Esq., M.A., 7 Church Street, Caermarthen; Collet Homersham, Esq., M.Inst.C.E., 19 Buckingham Street, Adelphi, W.C.; and Joseph B. Tyrrell, Esq., Geological Survey of Canada, Ottawa, Canada, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On Fossil Chilostomatous Bryozoa from Mount Gambier, South Australia." By Arthur W. Waters, Esq., F.L.S., F.G.S.

2. "*Thamniscus*: Permian, Carboniferous, and Silurian." By George W. Shrubsole, Esq., F.G.S.

3. "On the Occurrence of a new Species of *Phyllopora* in the Permian Limestones." By George W. Shrubsole, Esq., F.G.S.

4. "On the Relations of the Eocene and Oligocene Strata in the Hampshire Basin." By Prof. John W. Judd, F.R.S., Sec.G.S.

May 10, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Arthur Leech, Esq., Arlington House, Newcastle, Staffordshire, was elected a Fellow, and Professor L. Rütimeyer a Foreign Member of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On the Relations of *Hybocrinus*, *Baerocrinus*, and *Hybocystites*." By P. Herbert Carpenter, Esq., M.A. Communicated by Prof. P. Martin Duncan, M.B., F.R.S., V.P.G.S.

2. "On the Madreporaria of the Inferior Oolite of the Neighbourhood of Cheltenham and Gloucester." By R. F. Tomes, Esq., F.G.S.

3. "On the Exploration of two Caves in the Neighbourhood of Tenby." By Ernest L. Jones, Esq. Communicated by Prof. W. Boyd Dawkins, F.R.S., F.G.S.

4. "Note on the Comparative Specific Gravities of Molten and Solidified Vesuvian Lavas." By H. J. Johnston-Lavis, Esq., F.G.S.

[Abstract.]

From some experiments made on Vesuvian lava, Prof. Palmieri in 1875 expressed the opinion that its specific gravity, when molten, might be as high as 5·0, though when cooled it is only 2·7. The

author described the results of experiments made in December 1881 on some lava flowing across the Atrio del Cavallo. Favourable circumstances enabled him to gain a position above a perfectly molten stream, the surface of which was protected from radiation by the heated walls of a tunnel which the lava had already formed by cooling of the crust. On to this were dropped, from a height of $1\frac{1}{2}$ yard :—(*a*) light scoria ; this floated on the surface until lost to view (the stream could be watched for 150 yards or so): (*b*) fairly solid lava, with some vesicular cavities; this slowly sank, until after some distance it disappeared ; (*c*) the most compact lava that could be found, in which, however, were a few small cavities; this sank rapidly, the molten rock welling up round it. The author considered that these experiments demonstrate that the cooled lava is more dense than the molten, and that the apparently contradictory results obtained by Prof. Palmieri were due to the fact that the surface of the stream, by loss of heat, had become viscid, so that the solid material floated, though of greater density. The author concluded by citing other confirmatory evidence of his view.

The following specimens were exhibited :—

Specimens of Corals from the Inferior Oolite, exhibited by R. F. Tomes, Esq., in illustration of his paper.

Specimens of Crinoids, exhibited by P. H. Carpenter, Esq., in illustration of his paper.

Antlers of *Cervus* &c., exhibited by John Gunn, Esq.

The original of *Hybodus Bechi*, Charlesworth, a specimen of the rare fish *Macropoma Mantelli*, and various other fossils, exhibited by E. Charlesworth, Esq.

May 24, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair

The List of Donations to the Library was read.

Four models were presented by Dr. Reyer, illustrating his memoirs on the Karst, Predazzo, &c.

The following communications were read :—

1. "On the Geology of Costa Rica." By George Attwood, Esq., F.G.S., F.C.S., Assoc. Memb. Inst.C.E.; with an Appendix by W. H. Hudleston, Esq., M.A., F.G.S., F.C.S.

2. "On a remarkable Dinosaurian Coracoid from the Wealden of Brook, in the Isle of Wight, preserved in the Woodwardian Museum of the University of Cambridge, probably referable to *Ornithopsis*." By Prof. H. G. Seeley, F.R.S., F.L.S., F.G.S., &c.

3. "On the Newer Pliocene Period in England." By S. V. Wood, Esq., F.G.S. (Concluding Part.)

The following specimens were exhibited:—

Specimens of rocks and microscopic sections, exhibited by G. Attwood, Esq., in illustration of his paper.

A Dinosaurian Coracoid, exhibited by Prof. T. McK. Hughes in illustration of Prof. Seeley's paper.

June 7, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Alfred Morris, Esq., C.E., Athenæum Club, Sydney, N.S.W., and William Henry Watson, Esq., F.C.S., The Folds, Bolton-le-Moors, were elected Fellows of the Society.

The List of Donations to the Library was read.

A specimen of *Platax altissimus* from the Eocene Tertiary of Monte Bolca was presented to the Museum by Lieut.-Gen. Randolph.

The following names of Fellows of the Society were read out for the first time in conformity with the Bye-Laws (Sect. VI. B, Art. 6), in consequence of the non-payment of the arrears of their contributions:—James Duigan, Esq., E. G. Dyke, Esq., Joseph Lucas, Esq., M. F. Maury, Esq., H. G. Vennor, Esq., Ezekiel Williamson, Esq.

The following communications were read:—

1. The President read the following note, forwarded by Don Manuel F. de Castro, Director of the Geological Survey of Spain:—"On the Discovery of Triassic Fossils in the Sierra de Gador, Province of Almeria, Spain."

"The metalliferous limestone of the Sierra de Gador, owing to no fossil remains having been found prior to this occasion, has been a perfect puzzle to all geologists for the last fifty years.

"MM. Maestre, Amar de la Torre, Pernolet, Ansted, and Cooke considered these limestones to belong to the Transition series, the former taking them as representatives of the Mountain Limestones of other parts of Europe. M. Prado hinted that they might be Devonian; whilst M. Willkomm, in the geological map published to accompany his botanical researches in Spain, considered them Silu-

rian. Lately MM. Botella and Vilanova, in their respective maps, have marked them as belonging to the Permian series; whilst M. de Verneuil, coming nearer to the truth, took the whole of the limestones to the south of Granada and the Sierra de Gador as Triassic, though in doubt ("Trias incertain").

"Under these circumstances, I was commissioned by the Director of the Geological Survey of Spain to investigate the S.W. portion of the Province of Almeria, which comprises the Sierra de Gador. In February last I had the good fortune of discovering abundant fossil remains in different parts of the Sierra de Gador, which perfectly fix the age of the metalliferous limestones of this part of Spain.

"The whole series of rocks forming this *sierra*, resting on the mica-schists and slates of the Sierra Nevada, is a succession of black, white, and purple talcose schists at the base, which alternate with some beds of yellowish and porous limestone, and which pass through a considerable thickness of grey limestones and slates, and, precisely where the fossils have been found, to the metalliferous limestone of Sierra de Gador, which appears to form the top of this interesting formation.

"The fossils found belong to the following genera:—*Myophoria* (*M. lævigata* and *M. Goldfussi*), *Hinnites*, *Monotis*, *Avicula* (*A. Bronni*), *Myacites*, *Rissoa*, and many others difficult to determine.

"The places where the fossils have been found are the following:—on the southern slopes of the Sierra de Gador, in the Rambla del Cañuelo; midway on the road from Felix to Marchal; and in the place named La Solana del Fondon, to the left of the river Andarax, following the track between the mine Sebastopol and the town of El Fondon.

"JOAQUIN GONZALO Y XAVIER."

2. "The Girvan Succession.—Part I. Stratigraphical." By Charles Lapworth, Esq., F.G.S., Professor of Geology in the Mason Science College, Birmingham.

3. "Notes on the *Annelida tubicola* of the Wenlock Shales, from the Washings of Mr. George Maw, F.G.S." By George Robert Vine, Esq. Communicated by Prof. P. Martin Duncan, M.B., F.R.S., V.P.G.S.

4. "Description of part of the Femur of *Nototherium Mitchelli*." By Prof. Owen, C.B., F.R.S., F.G.S., &c.

5. "On *Helicopora latispiralis*, a new Spiral Fenestellid from the Upper Silurian Beds of Ohio, U.S." By E. W. Claypole, Esq., B.A., B.Sc. (Lond.), F.G.S.

The following were exhibited:—

Specimens exhibited by G. R. Vine, Esq., in illustration of his paper.

An old manuscript, in Spanish, relating to Assaying of Gold and Silver and valuation of Gems; and a manuscript 'Doctrina cristiania' in Quiché, originally obtained from one of the Jesuit fathers, and representing a language contemporary with the Aztec of Central America, exhibited by G. Attwood, Esq.

June 21, 1882.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Robert Bruce Napoleon Walker, Esq., J.P., 146 Cambridge Street, S.W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-Laws (Sect. VI. B, Art. 6), in consequence of the non-payment of the arrears of their contributions:—James Duigan, Esq., E. G. Dyke, Esq., Joseph Lucas, Esq., M. F. Maury, Esq., Ezekiel Williamson, Esq.

The President announced that he had received the following letter from Professor Daubrée, F.M.G.S.:—

"Londres, le 17 Juin, 1882.

"Monsieur le Président,—

"Depuis que la Société Géologique de Londres m'a fait le grand honneur de me décerner la médaille de Wollaston, j'avais le désir de venir personnellement lui exprimer ma vive reconnaissance, et ces jours-ci, en quittant Paris, j'avais l'espoir d'assister à la séance de Mercredi 21.

"Malheureusement, je me trouve obligé de rentrer sans retard, par suite de devoirs professionnels à remplir.

"C'est aussi un vif regret que je manque de si peu de jours le plaisir de me réunir à mes collègues de la Société Géologique de Londres.

"Veuillez me permettre, Monsieur le Président, de vous prier d'être auprès d'eux l'interprète de mes sentiments. Ce sera un dédommagement pour moi.

"Veuillez agréer aussi, Monsieur le Président, l'expression de la considération la plus distinguée de votre très dévoué confrère,

"A. Daubrée."

"Monsieur Hulke,

"*Président de la Société Géologique de Londres, &c. &c. &c.*"

The following communications were read:—

1. "On *Thecospondylus Horneri*, a new Dinosaur from the Hastings Sand, indicated by the Sacrum and the Neural Canal of the Sacral Region." By Prof. H. G. Seeley, F.R.S., F.G.S.

2. "On the Dorsal Region of the Vertebral Column of a new Dinosaur, indicating a new genus, *Sphenospondylus*, from the Wealden of Brook, in the Isle of Wight, preserved in the Woodwardian Museum of the University of Cambridge." By Prof. H. G. Seeley, F.R.S., F.G.S.

3. "On Organic Remains from the Upper Permian Strata of Kargalinsk in Eastern Russia." By W. H. Twelvetrees, Esq., F.G.S.

4. "The Rhætics of Nottinghamshire." By E. Wilson, Esq., F.G.S.

5. "On the Silurian and Cambrian Strata of the Baltic provinces of Russia, as compared with those of Scandinavia and the British Islands." By Dr. F. Schmidt. Communicated by Dr. H. Woodward, F.R.S., F.G.S.

6. "On Chilostomatous Bryozoa from Bairnsdale (Gippsland)." By A. W. Waters. Esq., F.G.S.

7. "The Silurian Species of *Glauconome*, and a suggested Classification of the Palæozoic Polyzoa." By G. W. Shrubsole, Esq., F.G.S., and G. R. Vine, Esq.

[Abstract.]

The authors discussed the history of our knowledge of the genus *Glauconome*, and especially of the Silurian species. They then characterized the genus, to which they refer only the Bala species formerly regarded as identical with *G. disticha*, Goldf., but which they describe as *G. Sedgwickii*, Shrubs. *Glauconome disticha*, Goldf., from the Wenlock of Dudley, is taken as the type of a new genus *Arcanopora*.

The authors then remarked upon the characters on which the classification of the Polyzoa is founded, drawn from the study of the recent forms, and stated that throughout the Cainozoic and Mesozoic series no Polyzoa are known which cannot be referred to the recognized groups. Many Palæozoic forms are in a different case. The orifices seen on the surface are not, in many cases, the mouths of the cells, but those of what the authors call *vestibules*, beneath which the true cell-mouth is concealed. For these types they propose to found a new suborder under the name of CRYPTOSTOMATA, characterized by having the zoœcia subtubular, or, in section, slightly angular, and the orifice surrounded by a vestibule or otherwise concealed. The families referred to this group are the Ceramoporidæ, Ptilodictyidæ, and Arcanoporidæ.

8. "On the Cause of the Depression and Re-elevation of the Land during the Glacial Period." By T. F. Jamieson, Esq., F.G.S.

[Abstract.]

The author commenced by noticing the theory advanced by Adhémar and Croll, according to which the submergence was due to the effect of a polar ice-cap causing a displacement of the earth's centre of gravity and thereby drawing the ocean towards the ice-covered pole, and proceeded to show that this theory is opposed to the geological evidence, according to which the amount of submergence has been unequal in adjacent areas and along the same parallels of latitude, showing that the movement has been in the land, and not in the sea. The facts of submergence also prove that no such cap of ice could have existed at the time in the northern regions. Sundry other objections were also pointed out. The author then went on to state his own hypothesis, which is to the effect that the depression of the land was caused by the weight of ice laid upon it, and the re-elevation by the disappearance of the ice. The amount of depression would depend partly on the weight of ice and partly on the elasticity or yielding nature of the ground beneath it. He then proceeded to consider what was the weight of ice that probably existed, and referred to the elastic and flexible nature of the earth's crust, as evinced by earthquakes &c.

He further considered the relation of time to pressure, and touched upon the probable rate of subsidence, which he supposes to have been very slow and gradual. The recovery of level, he thinks, would also be very gradual, and probably, in most cases, not complete.

He next proceeded to show how his hypothesis is borne out by an appeal to geological evidence in various countries, taking England, Ireland, North America, and Greenland as examples. He further pointed out its application to the facts connected with the loess beds, Fjord latitudes, and lake-basins, and concluded with some observations on the remarkable connexion between glaciation and submergence in all countries.

The following specimens were exhibited:—

Remains of a small species of Moa (*Dinornis didulus*, Owen, sp. n.) from New Zealand, showing portions of the skin and feathers, exhibited by Dr. H. Woodward.

Specimens of *Sphenospondylus* and *Thecospondylus Horneri*, exhibited by Prof. H. G. Seeley, in illustration of his papers.

Specimens exhibited by W. H. Twelvetrees, Esq., and E. Wilson, Esq., in illustration of their papers.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1881–82.

I. ADDITIONS TO THE LIBRARY.

1. Periodicals and Publications of Learned Societies.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy, The. No. 477. 1881.

——. Nos. 478–504. 1881.
Samuel Sharpe, 105.

——. Nos. 505–528. 1882.
Charles Darwin, 306.

Adelaide. Royal Society of South Australia. Transactions and Proceedings and Report. Vol. iv. 1880–81. 1882.

G. Scoular. A Sketch of the Geology of the district around Manoora, Hundred of Saddleworth, 37.—W. Rutt. Notes upon a Boring at Port Wakefield, 41.—R. Tate. The Geology about Port Wakefield, 45.—T. C. Cloud. Mineralogical Notes from the Laboratory of the Wallaroo smelting works, 50.—J. G. O. Tepper. Sketch of a Geological and Physical History of Hundred Cunningham and neighbouring regions, 61.—R. Tate. Geology in its Relation to Mining and Subterranean Water-supply in South Australia, 113.—R. Tate. Notes on the Geology about Franklin Harbour, west side of Spencer's Gulf, 143.—R. Tate. Geological Sections about Wellington or North-east shore of Lake Alexandrina, 144.—G. L. Debney. Notes on the Physical and Geological Features about Lake Eyre, 145.

Analyst, The. Vol. vi. Nos. 64–69. 1881.

——. Vol. vii. Nos. 70–74. 1882.

Annals and Magazine of Natural History. Ser. 5. Vol. viii. Nos. 43–48. 1881. *Purchased.*

G. C. Wallich. Supplementary Notes on the Flints and the Lithological Identity of the Chalk and Recent Calcareous Deposits in the Ocean, 46.—T. Stock. On some British Specimens of the "Kammplatten" or "Kammleisten" of Professor Fritsch, 90.—J. F. Whiteaves. On some remarkable fossil Fishes from the Devonian rocks of Scaumenac Bay, in

the province of Quebec, 159.—R. P. Whitfield. On the Nature of *Dictyophyton*, 237.—J. W. Dawson. Note on the Structure of a Specimen of *Uphantænia* from the Collection of the American Museum of Natural History, New York city, 237.—T. Rupert Jones. Notes on the Palæozoic Bivalved Entomostraca. No. XII. Some Cambrian and Silurian *Leperditiæ* and *Primitiæ*, 332.—E. D. Cope. Note on the Structure of the Posterior Foot of *Toxodon*, 389.—O. C. Marsh. Jurassic Birds and their Allies, 452.—S. H. Scudder. The Tertiary Lake-basin of Florissant, Colorado, 458.

Annals and Magazine of Natural History. Ser. 5. Vol. ix. Nos. 49–54. 1882. *Purchased.*

J. Hopkinson. On some Points in the Morphology of the Rhabdophora or true Graptolites, 54.—O. C. Marsh. Classification of the Dinosauria, 79.—F. Schmidt and T. Rupert Jones. On some Silurian *Leperditiæ*, 168.—E. D. Cope. The oldest Artiodactyle, 204.—E. D. Cope. The Characters of the Tæniodontia, 205.—E. D. Cope. New Forms of Coryphodontidæ, 211.—E. D. Cope. An Anthropomorphous Lemur, 212.—R. Etheridge, jun., and P. H. Carpenter. On certain Points in the Morphology of the Blastoidea, with Descriptions of some new Genera and Species, 213.—De Quatrefages. Charles Darwin, 467.

Athenæum (Journal). No. 2800. 1881.

——. Nos. 2801–2827. 1881.

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——. Parts 642–648. 1881.

——. Parts 649–653. 1882.

Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. vii. Parts 54–56. 1881.

——. ——. ——. Vol. viii. Parts 57 and 58. 1882.

Basel. Schweizerische paläontologische Gesellschaft. Abhandlungen. Vol. viii. 1881. *Purchased.*

L. Rütimeyer. Beiträge zu einer natürlichen Geschichte der Hirsche, II. Theil.—Koby. Monographie des Polypiers jurassiques de la Suisse, 2e partie.—P. de la Harpe. Étude des Nummulites de la Suisse, 2e partie.—P. de Loriol. Monographie paléontologique de la zone à *Ammonites tenuilobatus* d'Oberbuchsiten, fin.

Bath Natural-History and Antiquarian Field Club. Proceedings. Vol. v. No. 1. 1882.

H. H. Winwood. A Fact in connexion with the Vobster Inversion, 24.—Excursion to Portskewet and the Severn Tunnel, 46.

Belfast Natural-History and Philosophical Society. Proceedings for the Session 1880–81. 1882.

J. J. Murphy. The Problem of Geological Climates, 19.—J. Wright, Notes on the Foraminifera: Genus *Lagena*, 108.

Belfast Naturalists' Field Club. Annual Report and Proceedings. Ser. 2. Vol. i. Part 7. 1881.

J. Wright. A List of Post-Tertiary Foraminifera of the North-east of Ireland, 149.—S. A. Stewart. A List of the Mollusca of the Boulder-clay of the North-east of Ireland, 165.

Berlin. Deutsche geologische Gesellschaft. Zeitschrift. Band xxxiii. Hefte 1–4. 1881.

A. Remelé. Zur Gattung *Palæonautilus*, 1.—A. E. von Nordenskiöld. Ueber drei grosse Feuermeteore, beobachtet in Schweden in den Jahren 1876 und 1877, 14.—A. Becker. Ueber die Olivinknollen im Basalt, 31.—Böhm. Die Bivalven der Schichten des *Diceras Münsteri* (Diceraskalk) von Kelheim, 67.—C. Schlüter. Ueber einige Anthozoen des Devon, 75.—P. Lehmann. Beobachtungen über Tektonik und Gletscherspuren im Fogarascher Hochgebirge, 109.—H. Bücking. Ueber die krystallinischen Schiefer von Attika, 118.—A. Nöllner. Ueber einige künstliche Umwandlungsproducte des Kryolithes, 139.—R. Klebs. Ueber Harze aus dem Samlande, 169.—H. B. Geinitz. Ueber Renthierfunde in Sachsen, 170. A. Remelé. *Strombolituites*, eine neue Untergattung der perfecten Lituiten, nebst Bemerkungen über die Cephalopoden-Gattung *Ancistroceras* Boll, 187.—M. Bauer. Das diluviale Diatomeenlager aus der Wilmsdorfer Forst bei Zinten in Ostpreussen, 196.—O. Lang. Ueber Sedimentär-Gesteine aus der Umgegend von Göttingen, 217.—E. Tietze. Zur Würdigung der theoretischen Speculationen über die Geologie von Bosnien, 282.—H. Credner. Die Stegocephalen (Labyrinthodonten) aus dem Rothliegenden des Plauen'schen Grundes bei Dresden, 298.—E. Kayser. Ueber einige neue devonische Brachiopoden, 331.—J. Haniel. Ueber *Sigillaria Brasserti*, Haniel, 338.—Sterzel. Ueber die Flora der unteren Schichten des Plauenschen Grundes, 339.—F. Nötling. Ueber einige Brachyuren aus dem Senon von Mästricht und dem Tertiär Norddeutschlands, 357.—J. Kühn.—Untersuchungen über pyrenäische Ophite, 372.—W. Dames. Geologische Reisenotizen aus Schweden, 405.—von Dechen. Ueber Bimsstein im Westerwalde, 442.—M. Neumayr. Die krystallinischen Schiefer in Attika, 454.—O. Weerth. Ueber die Localfacies des Geschiebelehms in der Gegend von Detmold und Herford, 465.—von Fritsch. Ueber tertiäre Säugethierreste in Thüringen, 476.—A. Remelé. Nachträgliche Bemerkungen zu *Strombolituites*, und *Ancistroceras* Boll, 478.—G. Steinmann. Ueber *Acanthospongia* aus böhmischem Silur, 481.—E. Kalkowsky. Ueber Hercynit im sächsischen Granulit, 533.—A. Rothpletz. Der Bergsturz von Elm, 540.—F. E. Geinitz. Beobachtungen im sächsischen Diluvium, 565.—M. Neumayr. Ueber *Loriola*, eine neue Echinidengattung, 570.—H. Credner. Die Stegocephalen aus dem Rothliegenden des Plauen'schen Grundes bei Dresden, 574.—F. M. Stapff. Geologische Beobachtungen im Tessinthal, 604.—E. Kayser. Ueber das Alter des Hauptquarzits der Wieder Schiefer und des Kahleberger Sandsteins im Harz; mit Bemerkungen über die hercynische Fauna im Harz, am Rhein und in Böhmen, 617.—E. Kalkowsky. Ueber den Ursprung der granitischen Gänge im Granulit in Sachsen, 629.—T. Ebert. Die tertiären Ablagerungen der Umgegend von Cassel, 654.—A. von Könen. Ueber die Gattung *Anoplophora* Sandbg. (*Uniona* Pohlig), 679.—A. Bargatzky. *Stachyodes*, eine neue *Stromatoporide*, 688.

——. Gesellschaft naturforschender Freunde. Sitzungsberichte, 1881. 1881.

Dames. Ueber Zähne von *Rhombodus* aus der obersenonen Tuffkreide von Mästricht, 1.—K. A. Lossen. Ueber den Zusammenhang der Lothablenkungswerthe auf und vor dem Harz mit dem geologischen Bau dieses Gebirges, 19.—F. Hilgendorf. Ueber "The Genesis of the Tertiary Species of *Planorbis* at Steinheim" by A. Hyatt, 95.

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H. Bücking. Vorläufiger Bericht über die geologische Untersuchung

von Olympia, 315.—Bauer. Ueber eine Methode, die Brechungscoëfficienten einaxiger Krystalle zu bestimmen, und über die Brechungscoëfficienten des Brucits, 958.—Roth. Zur Geologie der Umgebung von Neapel, 990.—Websky. Ueber das Vorkommen von Phenakit in der Schweiz, 1007.

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E. Reusch. Ueber gewundene Bergkrystalle, 133.—E. Beyrich. Ueber geognostische Beobachtungen G. Schweinfurth's in der Wüste zwischen Cairo and Suez, 163.—A. Arzruni. Untersuchung der vulcanischen Gesteine aus der Gegend von Abu-Zábel am Ismaïlia-Canal, 178.—G. vom Rath. Ueber eine massenhafte Exhalation von Schwefelwasserstoff in der Bucht von Mesolungi, 201.—A. Arzruni. Krystallographische Untersuchungen an sublimirtem Titanit und Amphibol, 369.

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R. Lehmann. Neue Beiträge zur Kenntniss der ehemaligen Strandlinien in anstehendem Gestein in Norwegen, 463.

Bern. Schweizer Alpenclub. Jahrbuch 1880–81. Jahrgang XVI. (1881); and Beilagen. *Purchased.*

E. Renevier. Orographie de la partie des Hautes-Alpes calcaires comprise entre le Rhône et le Rawyl, 3.—E. v. Fellenberg. Topographische und geologische Notizen aus dem Baltschiederthal, 253.

Birmingham. Midland Naturalist. Vol. ii. Nos. 23 & 24. 1879. *Presented by W. Whitaker, Esq., F.G.S.*

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J. W. Coombs. The Changes of Climate during Geological Periods, 77, 107.—J. Shipman. A Visit to the Cresswell Caves, 135.—E. Wilson. Fossil Fish-remains from the Carboniferous Limestone of South Derbyshire, 172.—W. J. Harrison. On Deep Borings in the South-east of England, 188.—J. J. H. Teall. Origin of the Rocks and Scenery of North Wales, 214, 237, 266.—E. Wilson. On the Occurrence of Foraminifera in the Carboniferous Limestone of Derbyshire, 220.

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H. W. Crosskey. Note on some Additions to the Fauna of the Post-Tertiary Bed at Bridlington, Yorkshire, 373.

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